WIM System Field Calibration and Validation Summary Report

Virginia SPS-1
SHRP ID – 510100

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1 Executive Summary

A WIM validation was performed on March 1 and 2, 2011 at the Virginia SPS-1 site located on route US-29 at milepost 12.8, 5.3 miles north of US 360.

This site was installed on November 04, 2006. The in-road sensors are installed in the southbound lane. The site is equipped with bending plate WIM sensors and IRD iSINC WIM controller. The LTPP lane is identified as lane 1 in the WIM controller. From a comparison between the report of the most recent validation of this equipment on December 04, 2008 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

The equipment is in working order. Electronic and electrical checks of the WIM components determined that the the equipment is operating within the manufacturer's tolerances. Further equipment discussion is provided in Section 3.

During the on-site pavement evaluation, there were no pavement distresses noted that may affect the accuracies of the WIM system. A visual observation of the trucks as they approach, traverse, and leave the sensor area indicated some bouncing in the LTPP lane as they cross the transition from asphalt to concrete pavement surfaces. The trucks appear to stop bouncing prior to the WIM scale sensors. Trucks appear to track down the center of the lane. Further pavement condition discussion is provided in Section 4.

Based on the criteria contained in the LTPP Field Operations Guide for SPS WIM Sites, Version 1.0 (05/09), this site is providing research quality loading data. The summary results of the validation are provided in Table 1-1 below.

Table 1-1 – Post-Validation Results – 02-Mar-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-2.0 ± 5.2%	Pass
Tandem Axles	±15 percent	-0.4 ± 5.1%	Pass
GVW	±10 percent	-0.7 ± 3.7%	Pass
Vehicle Length	±3.0 percent (1.7 ft)	0.1 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Truck speeds were manually collected for each test run by a radar gun and compared with the speed reported by the WIM equipment. For this site, the error in speed measurement was -0.5 ± 1.8 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Operations Guide for SPS WIM Sites. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

This site is providing research quality vehicle classification data for heavy trucks (Class 6 – 13). The heavy truck misclassification rate of 0.0% is within the 2.0% acceptability criterion for LTPP SPS WIM sites. The overall misclassification rate of 4.0% from the 100 truck sample (Class 4 – 13) was primarily due to the 3 cross-classifications of Class 3, 4, 5, and 8 vehicles.

Based on these findings, it is recommended that an expanded investigation focusing on vehicle classification issues indicated in this report be conducted. The study shall focus on the identification of the cause for the misclassifications and the development of recommendations to remedy these causes. This study may be conducted in conjunction with the next calibration and validation visit.

There were two test trucks used for the post-validation. They were configured and loaded as follows:

- The *Primary* truck was a Class 9 vehicle with air suspension on the tractor and trailer tandems, and standard (4 feet) tandem spacings. It was loaded with stone.

- The *Secondary* truck was a Class 9 vehicle with air suspension on the tractor tandem, air on the trailer tandem, standard tandem spacing on the tractor and standard tandem on the trailer. The Secondary truck was loaded with stone.

Prior to the validation, the test trucks were weighed and measured, cold tire pressures were taken, and photographs of the trucks, loads and suspensions were obtained (see Section 7). Axle length (AL) was measured from the center hub of the first axle to the center hub of the last axle. Axle spacings were measured from the center hub of the each axle to the center hub of the subsequent axle. Overall length (OL) was measured from the edge of the front bumper to the edge of the rear bumper. The test trucks were re-weighed at the conclusion of the validation. The average post-validation test truck weights and measurements are provided in Table 1-2.

Table 1-2 – Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.4	9.4	16.1	16.1	16.9	16.9	15.0	4.3	29.3	4.4	53.0	59.0
2	65.9	10.2	12.1	12.1	15.8	15.8	14.1	4.3	23.8	4.3	46.4	52.7

The posted speed limit at the site is 65 mph. During the testing, the speed of the test trucks ranged from to 45 to 67 mph, a variance of 22 mph.

During test truck runs, pavement temperature was collected using a hand-held infrared temperature device. The post-validation pavement surface temperatures varied from 26.8 to 70.4 degrees Fahrenheit, a range of 43.6 degrees Fahrenheit. The sunny weather conditions provided for attaining the desired 30 degree range in temperatures.

A review of the LTPP Standard Release Database 24 shows that there are 24 consecutive months of level “E” WIM data for this site. This site requires at least 3 additional years of data to meet the minimum of five years of research quality data.

2 WIM System Data Availability and Pre-Visit Data Analysis

To assess the quality of the current traffic data, a pre-visit analysis was conducted by comparing a two-week data sample from January 31, 2011 (Data) to the most recent Comparison Data Set (CDS) from December 05, 2008. The assessments performed prior to the site visits are used to develop reasonable expectations for the validation. The results of further investigations performed as a result of the analyses are provided in Section 5 of this report.

2.1 LTPP WIM Data Availability

A review of the LTPP Standard Release Database 24 shows that there are 2 years of level "E" WIM data for this site. Table 2-1 provides a breakdown of the available data for years 2007 through 2009.

Table 2-1 – LTPP Data Availability

Year	Total Number of Days in Year	Number of Months
2007	332	12
2008	365	12
2009	179	6

As shown in the table, this site requires 3 additional years of data to meet the minimum of five years of research quality data.

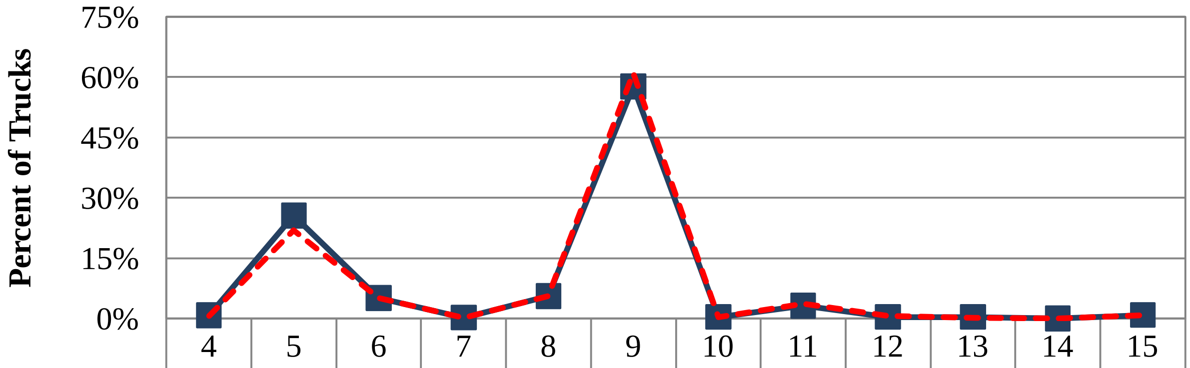
Table 2-2 provides a monthly breakdown of the available data for years 2007 through 2009.

Table 2-2 – LTPP Data Availability by Month

YEAR	Month												No. of Months
	1	2	3	4	5	6	7	8	9	10	11	12	
2007	27	28	30	15	19	30	31	31	29	31	30	31	12
2008	30	29	31	30	31	30	31	31	30	31	30	31	12
2009	31	28	31	30	31	28							6

2.2 Classification Data Analysis

The traffic data was analyzed to determine the expected truck distributions. This analysis provides a basis for the classification distribution study that was conducted on site. Figure 2-1 provides a comparison of the truck type distributions for the two datasets. As shown in the figure, the percentage of Class 9 trucks decreased while the percentage of Class 5 trucks has increased.



	4	5	6	7	8	9	10	11	12	13	14	15
Data	0.8%	25.5%	5.1%	0.2%	5.5%	57.7%	0.4%	3.1%	0.4%	0.4%	0.0%	0.9%
CDS	0.7%	21.9%	5.0%	0.1%	5.6%	61.1%	0.3%	3.6%	0.6%	0.2%	0.0%	0.8%

Figure 2-1 – Comparison of Truck Distribution

Table 2-3 provides statistics for the truck distributions at the site for the two periods represented by the two datasets. The table shows that according to the most recent data, the most frequent truck types crossing the WIM scale are Class 9 (57.7%) and Class 5 (25.5%). Table 2-3 also provides data for vehicle Classes 14 and 15. Class 14 vehicles are vehicles that are reported by the WIM equipment as having irregular measurements and cannot be classified properly, such as negative speeds from vehicles passing in the opposite direction of a two-lane road. Class 15 vehicles are unclassified vehicles. The table indicates that 0.9 percent of the vehicles at this site are unclassified.

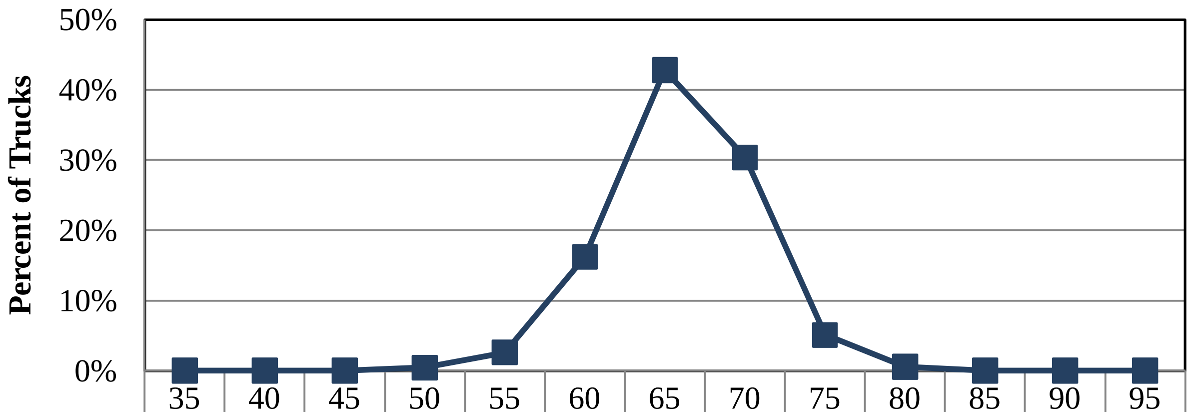
Table 2-3 – Truck Distribution from W-Card

Vehicle Classification	CDS		Data		Change
	Date				
	12/5/2008		1/31/2011		
4	87	0.7%	88	0.8%	0.1%
5	2823	21.9%	2786	25.5%	3.6%
6	648	5.0%	556	5.1%	0.1%
7	19	0.1%	23	0.2%	0.1%
8	721	5.6%	605	5.5%	-0.1%
9	7859	61.1%	6293	57.7%	-3.3%
10	45	0.3%	39	0.4%	0.0%
11	464	3.6%	342	3.1%	-0.5%
12	81	0.6%	41	0.4%	-0.3%
13	24	0.2%	39	0.4%	0.2%
14	0	0.0%	0	0.0%	0.0%
15	102	0.8%	94	0.9%	0.1%

From the table it can be seen that the number of Class 9 vehicles has decreased by 3.3 percent from December 2008 and January 2011. Changes in the number of heavier trucks may be attributed to seasonal variations in truck distributions. During the same time period, the number of Class 5 trucks increased by 3.6 percent. These differences may be attributed to small sample size used to develop vehicle class distributions, changes in the use of the roadway for local deliveries, cross-classifications of type 3 and 5 vehicles, as well as natural variations in truck volumes.

2.3 Speed Data Analysis

The traffic data received from the Phase II Contractor was analyzed to determine the expected truck speed distributions. This will provide a basis for determining the speed of the test trucks during validation testing. The CDS distribution of speeds is shown in Figure 2-2.



	35	40	45	50	55	60	65	70	75	80	85	90	95
Data	0.0%	0.0%	0.0%	0.5%	2.6%	16.2	42.8	30.4	5.1%	0.6%	0.0%	0.0%	0.0%

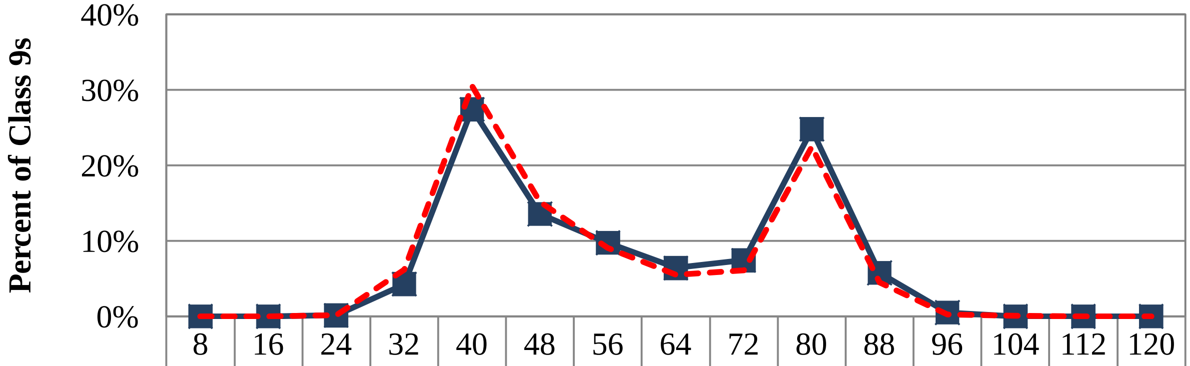
Figure 2-2 – Truck Speed Distribution – 27-Jan-11

As shown in Figure 2-2, the majority of the trucks at this site are traveling between 60 and 70 mph. The posted speed limit at this site is 65 and the 85th percentile speed for trucks at this site is 68 mph. The range of truck speeds for the validation will be 45 to 65 mph.

2.4 GVW Data Analysis

The traffic CDS data received from the Regional Support Contractor was analyzed to determine the expected Class 9 GVW distributions. Figure 2-3 shows a comparison between GVW plots generated using a two-week W-card sample from January 2011 and the Comparison Data Set from December 2008.

As shown in Figure 2-3, the percentage of unloaded trucks has decreased while the number of loaded trucks has increased between the December 2008 Comparison Data Set (CDS) and the January 2011 two-week sample W-card dataset (Data).



	8	16	24	32	40	48	56	64	72	80	88	96	104	112	120
Data	0.0%	0.0%	0.1%	4.3%	27.4	13.5	9.7%	6.4%	7.4%	24.8	5.8%	0.5%	0.0%	0.0%	0.0%
CDS	0.0%	0.0%	0.2%	6.2%	30.5	15.1	9.1%	5.5%	6.1%	22.4	4.5%	0.3%	0.1%	0.0%	0.0%

Figure 2-3 – Comparison of Class 9 GVW Distribution

Table 2-4 is provided to show the statistical comparison for Class 9 GVW between the Comparison Data Set and the current dataset.

Table 2-4 – Class 9 GVW Distribution from W-Card

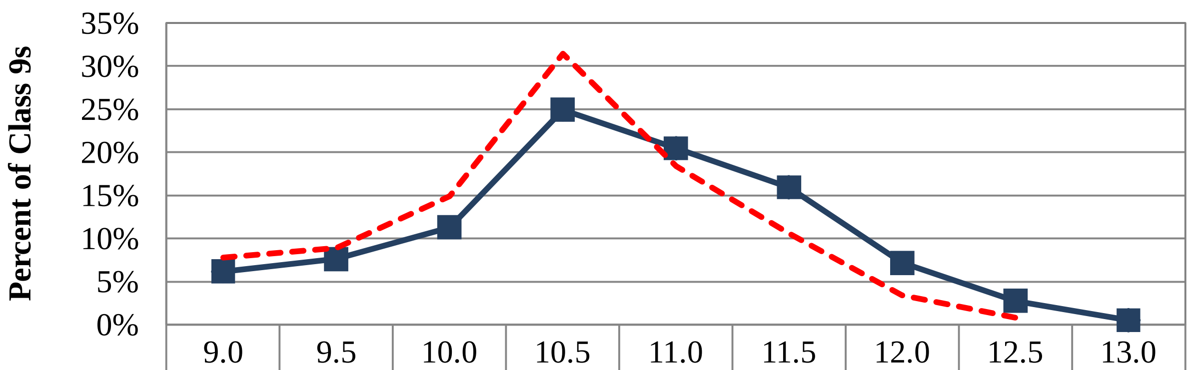
GVW weight bins (kips)	CDS		Data		Change
	Date				
	12/5/2008		1/31/2011		
8	0	0.0%	0	0.0%	0.0%
16	0	0.0%	0	0.0%	0.0%
24	16	0.2%	9	0.1%	-0.1%
32	483	6.2%	267	4.3%	-1.9%
40	2391	30.5%	1717	27.4%	-3.1%
48	1186	15.1%	848	13.5%	-1.6%
56	711	9.1%	610	9.7%	0.7%
64	433	5.5%	401	6.4%	0.9%
72	479	6.1%	465	7.4%	1.3%
80	1757	22.4%	1551	24.8%	2.3%
88	349	4.5%	360	5.8%	1.3%
96	20	0.3%	32	0.5%	0.3%
104	5	0.1%	0	0.0%	-0.1%
112	0	0.0%	0	0.0%	0.0%
120	0	0.0%	0	0.0%	0.0%
Average =	52.7 kips		55.2 kips		2.5 kips

As shown in the table, the number of unloaded class 9 trucks in the 32 to 40 kips range decreased by 3.1 percent while the number of loaded class 9 trucks in the 72 to 80 kips range increased by 2.3 percent. The number of overweight trucks increased during this time period by 1.5 percent. Based on the average Class 9 GVW values from the per vehicle records, the GVW average for this site increased by 4.7 percent from 52.7 kips to 55.2 kips.

2.5 Class 9 Front Axle Weight Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average front axle weight. This will provide a basis for the evaluation of the quality of the data by comparing the average front axle weight from the current data sample set with the expected average front axle weight average from the data comparison set.

Figure 2-4 shows a comparison between Class 9 front axle weight plots generated by using the two week W-card sample from January 2011 and the Comparison Data Set from December 2008.



	9.0	9.5	10.0	10.5	11.0	11.5	12.0	12.5	13.0
Data	6.2%	7.6%	11.3%	24.9%	20.5%	15.9%	7.2%	2.8%	0.5%
CDS	7.8%	8.9%	14.9%	31.4%	18.4%	10.6%	3.4%	0.8%	

Figure 2-4 – Distribution of Class 9 Front Axle Weights

It can be seen in the figure that the greatest percentage of trucks have front axle weights measuring between 10.5 and 11.0 kips. The percentage of trucks in this range has decreased between the December 2008 Comparison Data Set (CDS) and the January 2011 dataset (Data).

Table 2-5 provides the Class 9 front axle weight distribution data for the December 2008 Comparison Data Set (CDS) and the January 2011 dataset (Data).

Table 2-5 – Class 9 Front Axle Weight Distribution from W-Card

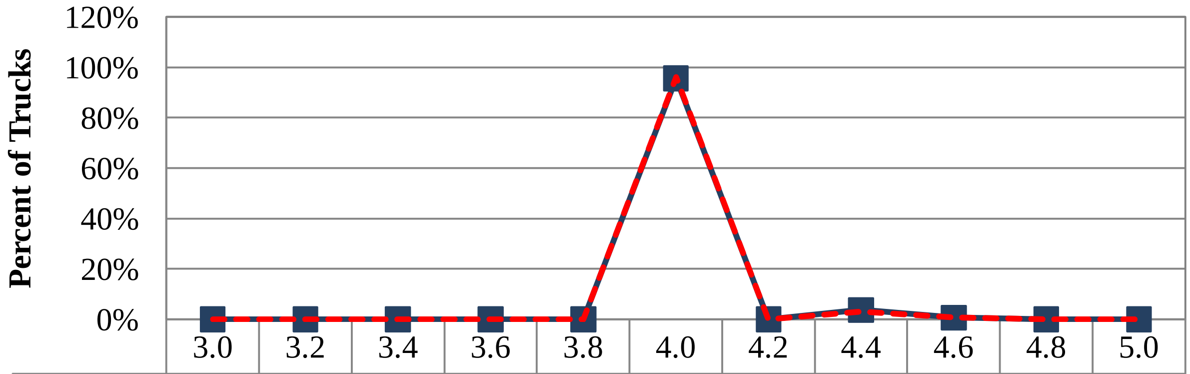
F/A weight bins (kips)	CDS		Data		Change
	Date				
	12/5/2008		1/31/2011		
9.0	276	3.5%	193	3.1%	-0.4%
9.5	609	7.8%	386	6.2%	-1.6%
10.0	695	8.9%	476	7.6%	-1.3%
10.5	1163	14.9%	706	11.3%	-3.6%
11.0	2456	31.4%	1559	24.9%	-6.5%
11.5	1436	18.4%	1279	20.5%	2.1%
12.0	831	10.6%	996	15.9%	5.3%
12.5	268	3.4%	448	7.2%	3.7%
13.0	64	0.8%	173	2.8%	1.9%
13.5	14	0.2%	33	0.5%	0.3%
Average =	10.7		10.9		0.2

The table shows that the average front axle weight for Class 9 trucks has increased by 0.2 kips, or 1.9 percent. According to the values from the per vehicle records, the average front axle weight for Class 9 trucks is 10.9 kips.

2.6 Class 9 Tractor Tandem Spacing Data Analysis

The CDS data received from the Regional Support Contractor was analyzed to determine the expected average tractor tandem spacing. This will provide a basis for the evaluation of the accuracy of the equipment distance and speed measurements by comparing the observed average tractor tandem spacing with the expected average tractor tandem spacing from the comparison data set.

The class 9 tractor tandem spacing plot in Figure 2-5 is provided to indicate possible shifts in WIM system distance and speed measurement accuracies.



	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.8	5.0
Data	0.0%	0.0%	0.0%	0.0%	0.0%	95.6%	0.0%	3.7%	0.7%	0.0%	0.0%
CDS	0.0%	0.0%	0.0%	0.0%	0.0%	96.1%	0.0%	3.1%	0.7%	0.0%	0.0%

Figure 2-5 – Comparison of Class 9 Tractor Tandem Spacing

As seen in the figure, the Class 9 tractor tandem spacings for the December 2008 Comparison Data Set and the January 2011 Data are identical.

Table 2-6 shows the Class 9 axle spacings between the second and third axles. .

Table 2-6 – Class 9 Axle 2 to 3 Spacing from W-Card

Tandem 1 spacing bins (feet)	CDS		Data		Change
	Date				
	12/5/2008		1/31/2011		
3.0	0	0.0%	0	0.0%	0.0%
3.2	0	0.0%	0	0.0%	0.0%
3.4	0	0.0%	1	0.0%	0.0%
3.6	0	0.0%	0	0.0%	0.0%
3.8	2	0.0%	2	0.0%	0.0%
4.0	7527	96.1%	5982	95.6%	-0.6%
4.2	0	0.0%	0	0.0%	0.0%
4.4	246	3.1%	231	3.7%	0.5%
4.6	53	0.7%	43	0.7%	0.0%
4.8	0	0.0%	0	0.0%	0.0%
5.0	2	0.0%	1	0.0%	0.0%
Average =	4.0		4.0		0.0

From the table it can be seen that the drive tandem spacing of Class 9 trucks at this site is between 3.8 and 5.0 feet. Based on the average Class 9 drive tandem spacing values from the per vehicle records, the average tractor tandem spacing is 4.0 feet, which is identical to the expected average of 4.0 feet from the CDS per vehicle records. Further analyses are performed during the validation and post-validation analysis.

2.7 Data Analysis Summary

Historical data analysis involved the comparison of the most recent Comparison Data Set (December 2008) based on the last calibration with the most recent two-week WIM data sample from the site (January 2011). Comparison of vehicle class distribution data indicates a 3.4 percent decrease in the number of Class 9 vehicles. Analysis of Class 9 weight data indicates that front axle weights have increased by 0.2 kips and average Class 9 GVW has increased by 4.9 percent for the January 2011 data. The data indicates an average truck tandem spacing of 4.0 feet, which is identical the expected average of 4.0 feet.

3 WIM Equipment Discussion

From a comparison between the report of the most recent validation of this equipment on December 04, 2008 and this validation visit, it appears that no changes have occurred during this time to the basic operating condition of the equipment.

3.1 Description

This site was installed on November 04, 2006 by International Road Dynamics. It is instrumented with bending plate weighing sensors and an IRD iSINC WIM Controller. As the installation contractor, IRD also performs routine equipment maintenance and data quality checks of the WIM data.

3.2 Physical Inspection

Prior to the pre-validation test truck runs, a physical inspection of all WIM equipment and support services equipment was conducted. No deficiencies were noted. Photographs of all system components were taken and are presented after Section 7.

3.3 Electronic and Electrical Testing

Electronic and electrical checks of all system components were conducted prior to the pre-validation test truck runs. Dynamic and static electronic checks of the in-road sensors were performed. All values for the WIM sensors and inductive loops were within tolerances. Electronic tests of the power and communication devices indicated that they were operating normally.

3.4 Equipment Troubleshooting and Diagnostics

The WIM system appeared to collect, analyze and report vehicle measurements normally. No troubleshooting actions were taken.

3.5 Recommended Equipment Maintenance

No unscheduled equipment maintenance actions are recommended.

4 Pavement Discussion

4.1 Pavement Condition Survey

During a visual distress survey of the pavement conducted from the shoulder, no areas of pavement distress that may affect the accuracy of the WIM sensors were noted.

4.2 Profile and Vehicle Interaction

Profile data was collected on July 13, 2010 by the North Atlantic Regional Support Contractor using a high-speed profiler, where the operator measures the pavement profile over the entire one-thousand foot long WIM Section, beginning 900 feet prior to WIM scales and ending 100 feet after the WIM scales. Each pass collects International Roughness Index (IRI) values in both the left and right wheel paths. For this site, 11 profile passes were made, 5 in the center of the travel lane and 6 that were shifted to the left and to the right of the center of the travel lane.

From a pre-visit review of the IRI values for the center, right, and left profile runs, the highest IRI value within the 400 foot approach section was 390 in/mi and is located approximately 313 feet prior to the WIM scale. These areas of the pavement were closely investigated during the validation visit, and truck dynamics in this area were closely observed. There is a pavement transition at this location and adverse truck dynamics were noted. However, the distresses observed at this location do not appear to influence truck dynamics in the WIM scale area.

Additionally, a visual observation of the trucks as they approach, traverse and leave the sensor area did not indicate any visible motion of the trucks that would affect the performance of the WIM scales. Trucks appear to track down the center of the lane.

4.3 LTPP Pavement Profile Data Analysis

The IRI data files are processed using the WIM Smoothness Index software. The indices produced by the software provide an indication of whether or not the pavement roughness may affect the operation of the WIM equipment. The recommended thresholds for WIM Site pavement smoothness are provided in Table 4-1.

Table 4-1 – Recommended WIM Smoothness Index Thresholds

Index	Lower Threshold (m/km)	Upper Threshold (m/km)
Long Range Index (LRI)	0.50	2.1
Short Range Index (SRI)	0.50	2.1
Peak LRI	0.50	2.1
Peak SRI	0.75	2.9

When all values are less than the lower threshold shown in Table 4-1, it is unlikely that pavement conditions will significantly influence sensor output. Values between the threshold values may or may not influence the accuracy of the sensor output and values above the upper threshold would lead to sensor output that would preclude achieving the research quality loading data.

The profile analysis was based on four different indices: Long Range Index (LRI), which represents the pavement roughness starting 25.8 m prior to the scale and ending 3.2 m after the scale in the direction of travel; Short Range Index (SRI), which represents the pavement roughness beginning 2.74 m prior to the WIM scale and ending 0.46 m after the scale; Peak LRI – the highest value of LRI within 30 m prior to the scale; and Peak SRI – the highest value of SRI between 2.45 m prior to the scale and 1.5 m after the scale. The results from the analysis for each of the indices for the right wheel path (RWP) and left wheel path (LWP) values for the 3 left, 3 right and 5 center profiler runs are presented in Table 4-2.

Table 4-2 – WIM Index Values

Profiler Passes			**Pass 1**	**Pass 2**	**Pass 3**	**Pass 4**	**Pass 5**	**Avg**
Left	LWP	LRI (m/km)	0.955	0.883	0.933			0.924
		SRI (m/km)	0.762	*0.487*	*0.491*			0.580
		Peak LRI (m/km)	0.961	0.937	1.032			0.977
		Peak SRI (m/km)	0.923	0.584	0.787			0.765
	RWP	LRI (m/km)	0.683	0.628	0.625			0.645
		SRI (m/km)	0.547	*0.345*	0.521			*0.471*
		Peak LRI (m/km)	0.688	0.704	0.696			0.696
		Peak SRI (m/km)	*0.738*	*0.661*	*0.721*			*0.707*
Center	LWP	LRI (m/km)	1.275	0.918	1.355	1.203	1.097	1.188
		SRI (m/km)	1.004	1.070	1.529	0.985	*0.450*	1.147
		Peak LRI (m/km)	**1.514**	**0.927**	**1.440**	**1.355**	**1.355**	**1.309**
		Peak SRI (m/km)	1.180	1.110	1.569	1.019	*0.685*	1.220
	RWP	LRI (m/km)	0.786	0.953	0.876	0.856	0.753	0.868
		SRI (m/km)	0.757	0.780	0.746	0.584	0.825	0.717
		Peak LRI (m/km)	0.814	0.954	0.886	0.856	0.762	0.878
		Peak SRI (m/km)	1.064	1.135	0.999	0.780	1.012	0.995
Right	LWP	LRI (m/km)	0.686	0.787	0.764			0.746
		SRI (m/km)	*0.474*	0.656	0.743			0.624
		Peak LRI (m/km)	0.720	0.789	0.778			0.762
		Peak SRI (m/km)	0.803	0.829	0.873			0.835
	RWP	LRI (m/km)	0.937	0.951	0.869			0.919
		SRI (m/km)	0.680	0.708	0.974			0.787
		Peak LRI (m/km)	0.937	0.951	0.888			0.925
		Peak SRI (m/km)	0.943	1.009	1.085			1.012

From Table 4-2 it can be seen that most of the indices computed from the profiles are between the upper and lower threshold values, with the remaining values under the lower threshold (shown in italics). The highest values, on average, are the Peak LRI values in the left wheel path of the center passes (shown in bold).

4.4 Recommended Pavement Remediation

No pavement remediation is recommended.

5 Statistical Reliability of the WIM Equipment

The following section provides summaries of data collected during the pre-validation, the calibration, and the post-validation test truck runs, as well as information resulting from the classification and speed studies. All analyses of test truck data and information on necessary equipment adjustments are provided.

5.1 Pre-Validation

The first set of test runs provides a general overview of system performance prior to any calibration adjustments for the given environmental, vehicle speed and other conditions.

The 40 pre-validation test truck runs were conducted on March 01, 2011, beginning at approximately 9:04 AM and continuing until 4:29 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with stone, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.

- A Class 9, 5-axle truck, loaded with stone, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tandem spacing on the trailer.

The test trucks were weighed prior to the pre-validation and were re-weighed at the conclusion of the pre-validation. The average test truck weights and measurements are provided in Table 5-1.

Table 5-1 - Pre-Validation Test Truck Weights and Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.4	9.4	16.1	16.1	16.9	16.9	15.0	4.3	29.3	4.4	53.0	59.0
2	66.0	10.2	12.2	12.2	15.7	15.7	14.1	4.3	23.8	4.3	46.4	52.7

Test truck speeds varied by 24 mph, from 44 to 68 mph. The measured pre-validation pavement temperatures varied 28.4 degrees Fahrenheit, from 41.2 to 69.6. The sunny weather conditions nearly provided for attaining the desired 30 degree temperature range. Table 5-2 provides a summary of the pre-validation results.

Table 5-2 – Pre-Validation Overall Results – 01-Mar-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	1.8 ± 7.7%	Pass
Tandem Axles	±15 percent	3.5 ± 4.5%	Pass
GVW	±10 percent	3.1 ± 3.4%	Pass
Vehicle Length	±3.0 percent (1.7 ft)	0.2 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement over all speeds was -0.6 ± 1.1 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.0 feet, and the speed and axle spacing measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

5.1.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 65 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-3.

Table 5-3 – Pre-Validation Results by Speed – 01-Mar-11

Parameter	95% Confidence Limit of Error	Low	Medium	High
		44.0 to 52.0 mph	52.1 to 60.1 mph	60.2 to 68.0 mph
Steering Axles	±20 percent	0.7 ± 7.9%	3.1 ± 8.8%	1.0 ± 7.0%
Tandem Axles	±15 percent	3.4 ± 4.3%	3.4 ± 2.9%	3.8 ± 7.9%
GVW	±10 percent	2.9 ± 3.4%	3.1 ± 2.7%	3.2 ± 5.7%
Vehicle Length	±3.0 percent (1.7 ft)	0.2 ± 1.1 ft	0.2 ± 1.0 ft	0.1 ± 1.8 ft
Vehicle Speed	± 1.0 mph	-0.3 ± 1.4 mph	-0.6 ± 1.0 mph	-0.8 ± 1.0 mph
Axle Length	± 0.5 ft [150mm]	-0.1 ± 0.0 ft	0.0 ± 0.1 ft	0.0 ± 0.1 ft

From the table, it can be seen that, on average, the WIM equipment overestimates all weights at all speeds. The range of errors is consistent at all speeds for steering axle weights. For other weights, the range in error is inconsistent with regard to speed and is greatest at the higher speeds. Speed does appear to have an effect on weight measurement errors at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following sections.

5.1.1.1 GVW Errors by Speed

As shown in Figure 5-1, the equipment overestimated GVW at all speeds. The range in error and bias appear to be marginally greater at the higher speeds.

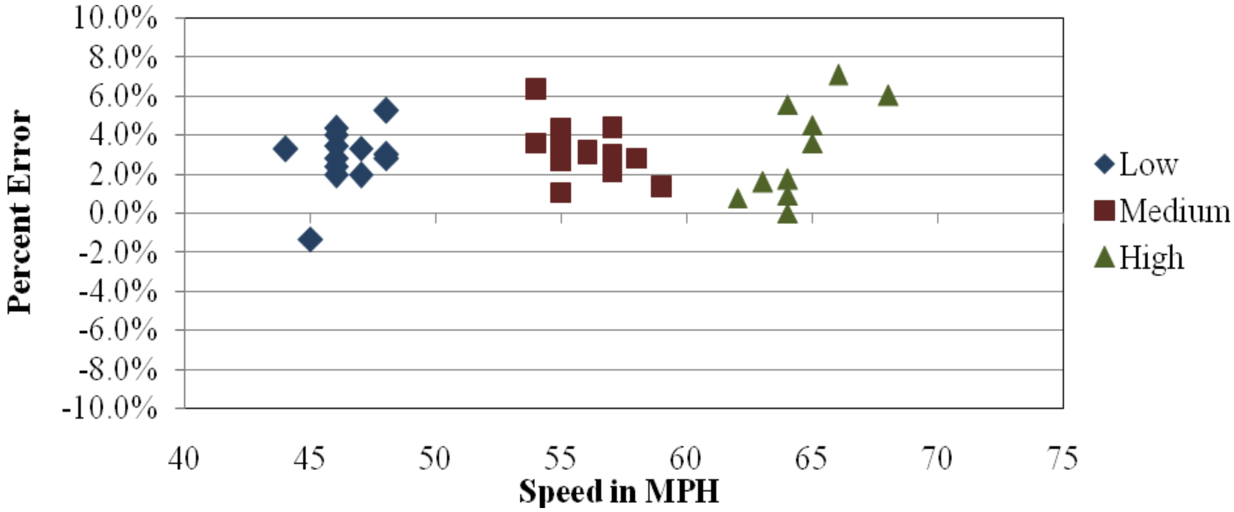


Figure 5-1 – Pre-Validation GVW Error by Speed – 01-Mar-11

5.1.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-2, the equipment estimates steering axle weights with reasonable accuracy at all speeds. The range in error appears to be greater at the medium speeds when compared with low and high speeds.

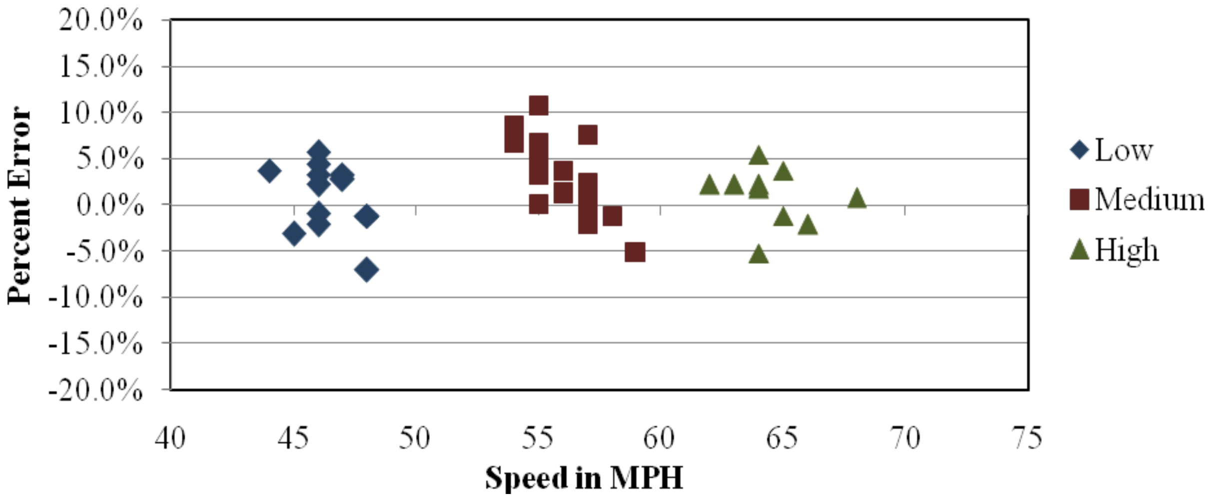


Figure 5-2 – Pre-Validation Steering Axle Weight Errors by Speed – 01-Mar-11

5.1.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-3, the equipment generally overestimates tandem axle weights at all speeds. As with GVW, the range in error is greater at the higher speeds.

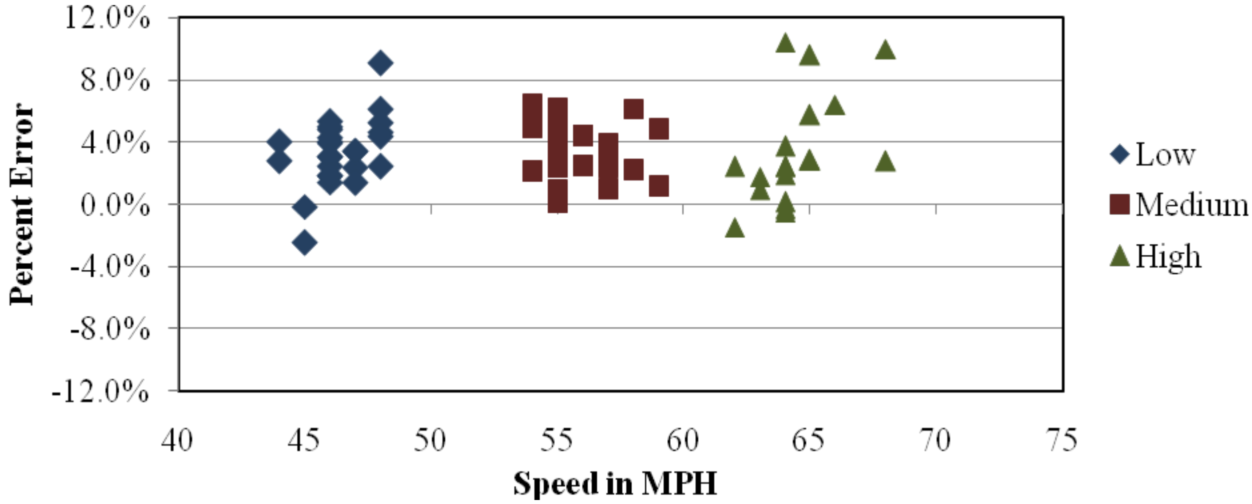


Figure 5-3 – Pre-Validation Tandem Axle Weight Errors by Speed – 01-Mar-11

5.1.1.4 GVW Errors by Speed and Truck Type

When the GVW error for each truck is analyzed as a function of speed, it can be seen that at the low and medium speeds, the WIM equipment precision and bias is similar for both the heavily loaded (*Primary)* truck and the partially loaded (*Secondary*) truck. At the higher speeds, GVW is overestimated by a greater degree for the Secondary truck than the Primary truck. Distribution of errors is shown graphically in Figure 5-4.

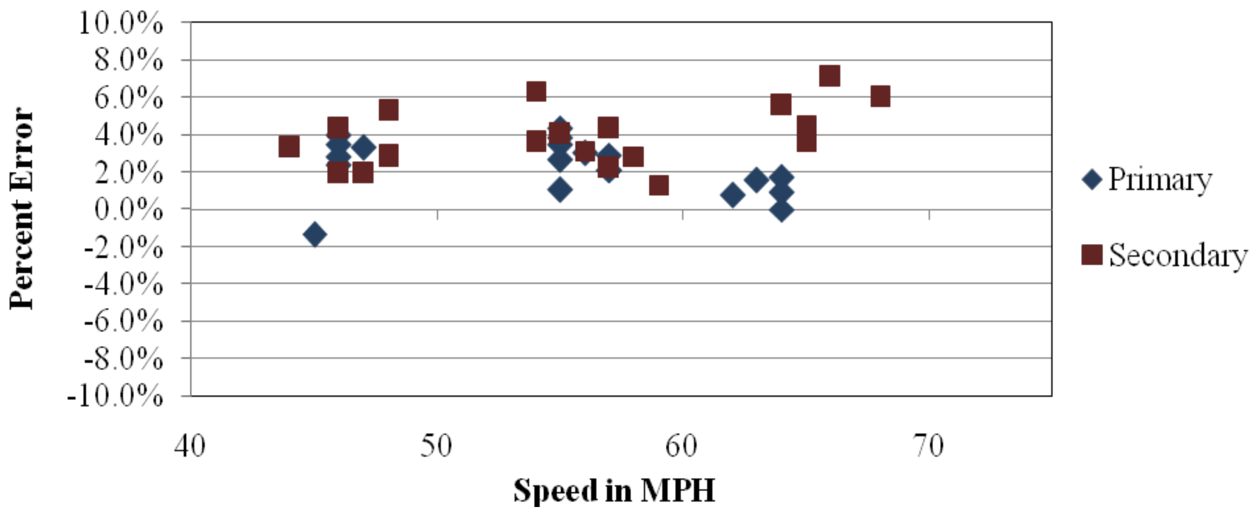


Figure 5-4 – Pre-Validation GVW Errors by Truck and Speed – 01-Mar-11

5.1.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from -0.1 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-5.

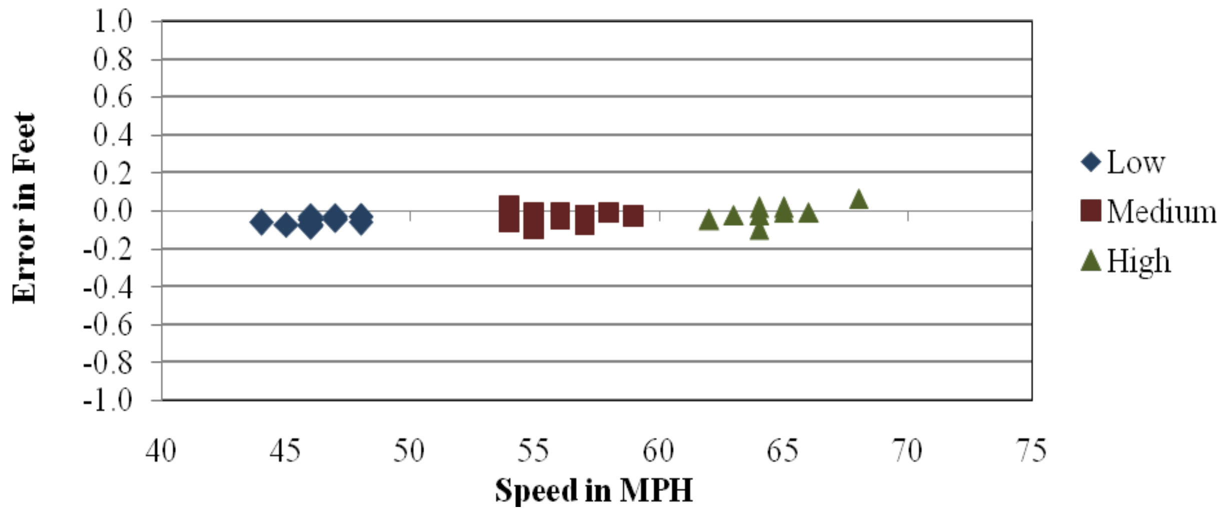


Figure 5-5 – Pre-Validation Axle Length Errors by Speed – 01-Mar-11

5.1.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measured overall vehicle length with reasonable consistently over the entire range of speeds, with an error range of -1.0 to 1.3 feet. Distribution of errors is shown graphically in Figure 5-6.

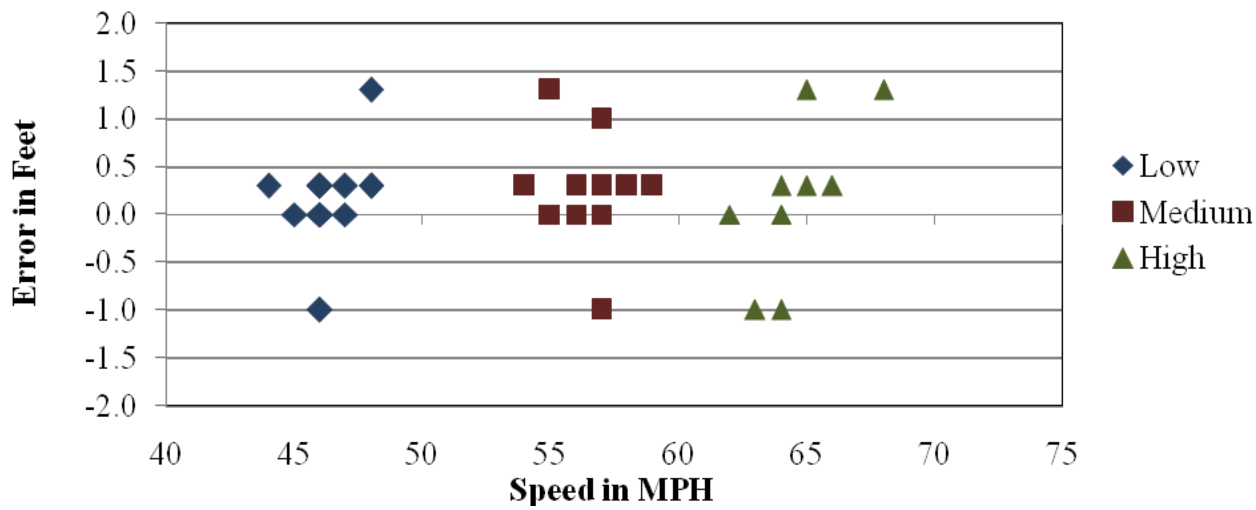


Figure 5-6 – Pre-Validation Overall Length Error by Speed – 01-Mar-11

5.1.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures varied 28.4 degrees, from 41.2 to 69.6 degrees Fahrenheit. The pre-validation test runs are being reported under two temperature groups – low and high, as shown in Table 5-4.

Table 5-4 – Pre-Validation Results by Temperature – 01-Mar-11

Parameter	**95% Confidence Limit of Error**	**Low**	**High**
		41.2 to 55.4 degF	**55.5 to 69.7 degF**
Steering Axles	±20 percent	1.5 ± 8.2%	1.9 ± 8.1%
Tandem Axles	±15 percent	2.6 ± 4.0%	4.0 ± 4.7%
GVW	±10 percent	2.3 ± 3.1%	3.5 ± 3.5%
Vehicle Length	±3.0 percent (1.7 ft)	0.2 ± 1.1 ft	0.1 ± 1.2 ft
Vehicle Speed	± 1.0 mph	-0.7 ± 1.0 mph	-0.5 ± 1.2 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle, and axle group weights.

5.1.2.1 GVW Errors by Temperature

From Figure 5-7, it can be seen that the equipment appears to overestimate GVW across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and GVW estimates at this site.

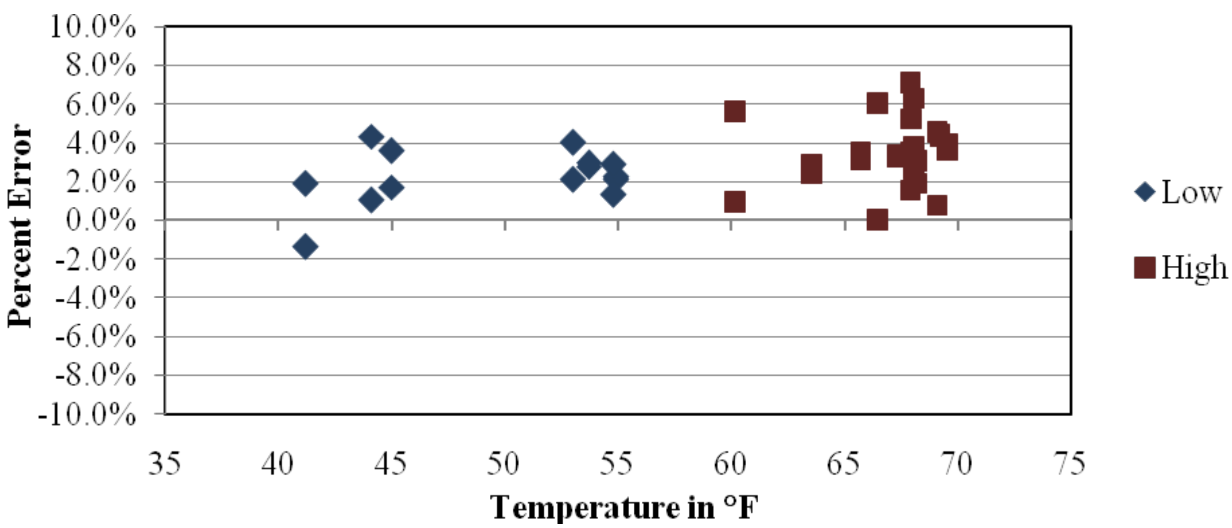


Figure 5-7 – Pre-Validation GVW Errors by Temperature – 01-Mar-11

5.1.2.2 Steering Axle Weight Errors by Temperature

Figure 5-8 illustrates that for steering axles, the WIM equipment appears to estimate steering axle weights with reasonable accuracy across the range of temperatures observed in the field. The range in error is similar for the two temperature groups.

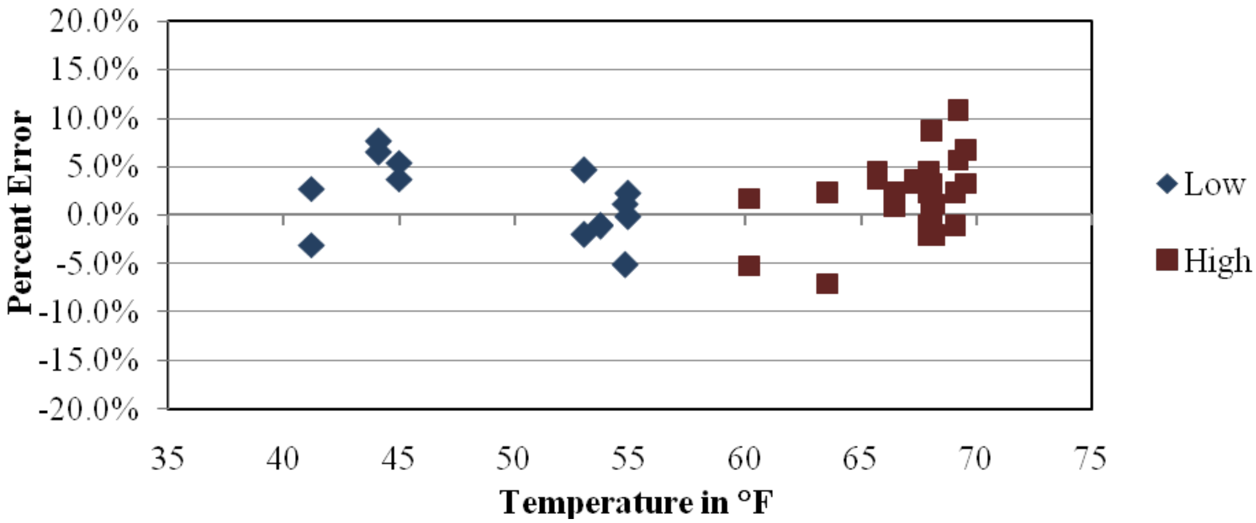


Figure 5-8 – Pre-Validation Steering Axle Weight Errors by Temperature – 01-Mar-11

5.1.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-9, the WIM equipment appears to overestimate tandem axle weights across the range of temperatures observed in the field. The range in tandem axle errors appears to be greater at the higher temperatures.

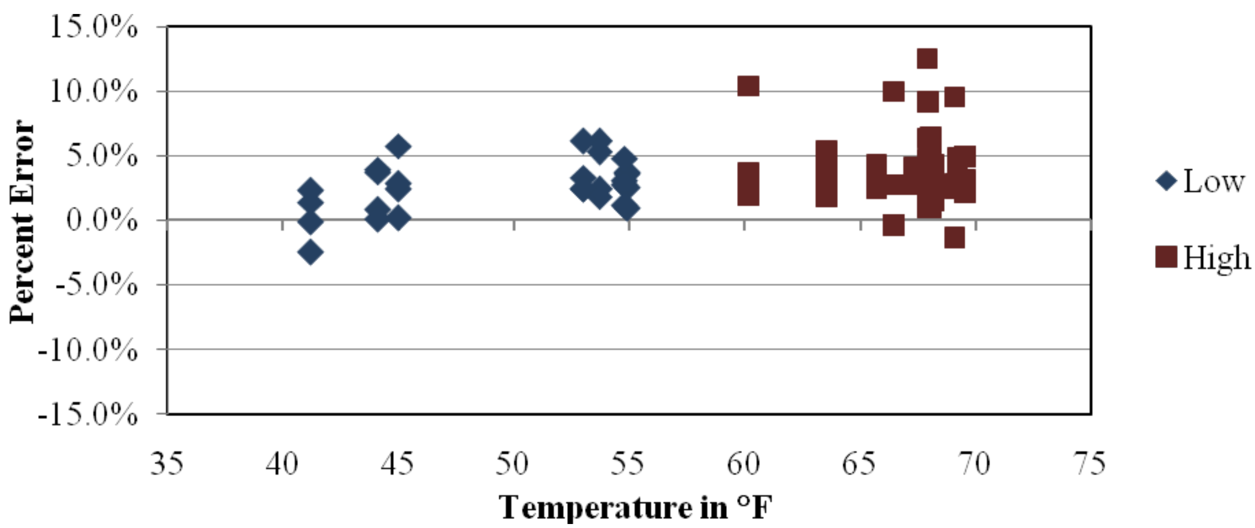


Figure 5-9 – Pre-Validation Tandem Axle Weight Errors by Temperature – 01-Mar-11

5.1.2.4 GVW Errors by Temperature and Truck Type

When analyzed for each test truck, GVW measurement errors for both trucks follow similar patterns where estimates for GVW error for both trucks are overestimated at all temperatures. GVW for the Secondary truck appears to be overestimated by a greater degree at the low and high temperatures. For both trucks, the range of errors and bias are consistent over the range of temperatures. Distribution of errors is shown graphically in Figure 5-10.

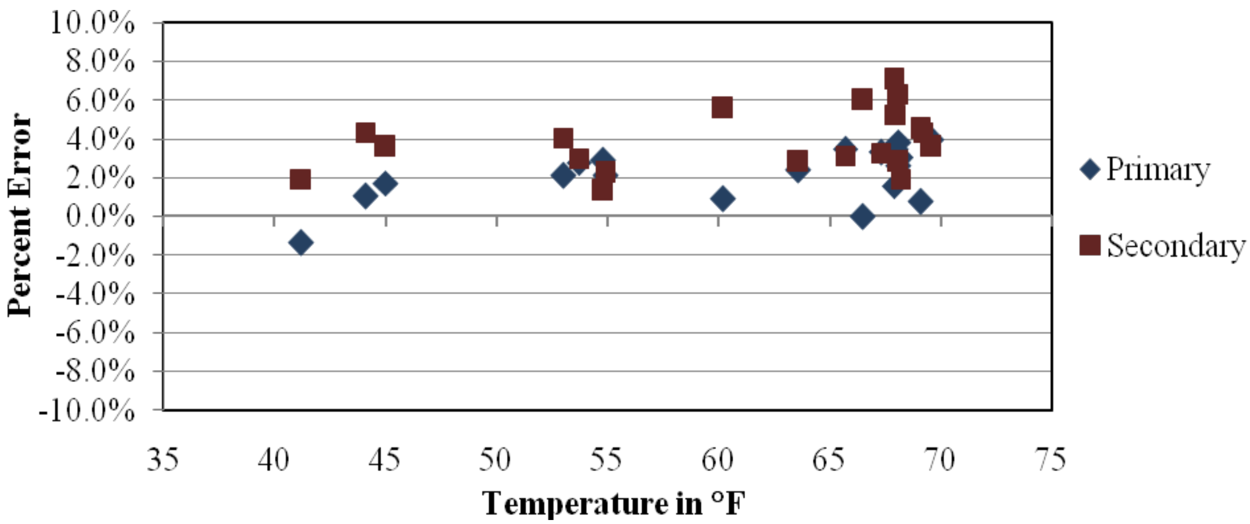


Figure 5-10 – Pre-Validation GVW Error by Truck and Temperature – 01-Mar-11

5.1.3 Classification and Speed Evaluation

The pre-validation classification and speed study involved the comparison of vehicle classification and speed data collected manually with the information for the same vehicles reported by the WIM equipment.

For the pre-validation classification study at this site, a manual sample of 100 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field. Table 5-5 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study.

Table 5-5 – Pre-Validation Classification Study Results – 01-Mar-11

Class	4	5	6	7	8	9	10	11	12	13
Observed Count	1	21	6	0	8	58	2	3	1	0
WIM Count	1	21	5	0	8	59	1	2	1	1
Observed Percent	1.0	21.0	6.0	0.0	8.0	58.0	2.0	3.0	1.0	0.0
WIM Percent	1.0	21.0	5.0	0.0	8.0	59.0	1.0	2.0	1.0	1.0
Misclassified Count	1	1	1	0	0	0	0	1	0	0
Misclassified Percent	100.0	4.8	16.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	0	0	0	1	0	0	0
Unclassified Percent	0.0	0.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0	0.0

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one class of vehicle but identified by the WIM equipment as another class of vehicle. For this site, there were five vehicles that were either misclassified or unclassified by the equipment. The misclassifications by pair are provided in Table 5-6.

Table 5-6 – Pre-Validation Misclassifications by Pair – 01-Mar-11

Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs
4/5	1	6/7	0	9/8	0
4/6	0	6/8	0	9/10	0
5/3	0	6/9	0	10/9	0
5/4	0	6/10	0	10/13	0
5/6	0	7/6	0	11/12	0
5/7	0	8/3	0	11/13	1
5/8	0	8/5	0	12/11	0
5/9	1	8/9	0	12/11	0
6/4	1	9/5	0	13/10	0

Based on the vehicles observed during the pre-validation study, the misclassification percentage is 1.3% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (4 – 15) is 4.0%.

As shown in the table, a total of 4 vehicles, including 2 heavy trucks (6 – 13) were misclassified by the equipment. One Class 6 was identified as a Class 4, and one Class 11 was identified as a Class 13 by the equipment. The causes for the misclassifications were not investigated in the field.

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-7.

Table 5-7 – Pre-Validation Unclassified Trucks by Pair – 01-Mar-11

Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs
3/15	0	7/15	0	11/15	0
4/15	0	8/15	0	12/15	0
5/15	0	9/15	0	13/15	0
6/15	0	10/15	1		

Based on the manually collected sample of the 100 trucks, 1.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites. The unclassified vehicle was a Class 10. The cause of the un-classification was not investigated in the field.

For speed, the mean error for WIM equipment speed measurement was -0.5 mph; the range of errors was 1.2 mph.

Based on these findings, it is recommended that an expanded investigation focusing on vehicle classification issues indicated in this report be conducted. The study shall focus on the identification of the cause for the misclassifications and the development of recommendations to remedy these causes. This study may be conducted in conjunction with the next calibration and validation visit.

5.2 Calibration

The WIM equipment required one calibration iteration between the pre- and post-validations. Information regarding the basis for changing equipment compensation factors, supporting data for the changes, and the resulting WIM accuracies from the calibrations are provided in this section. The operating system weight compensation parameters that were in place prior to the pre-validation are shown in Table 5-8.

Table 5-8 – Initial System Parameters – 02-Mar-11

Speed Point	MPH	Left	Right
		1	2
72	45	3422	3422
88	55	3422	3422
104	65	3422	3422
120	75	3422	3422
136	85	3422	3422
Axle Distance (cm)		370	
Dynamic Comp (%)		103	
Loop Width (cm)		180	

5.2.1 Calibration Iteration 1

5.2.1.1 Equipment Adjustments

For GVW, the pre-validation test truck runs produced an overall error of 3.1% and errors of 2.7%, 3.4%, and 3.3% at the 45, 55 and 65 mph speed points respectively. The errors for the 65 mph speed point were extrapolated to derive new compensation factors for the 75 mph and 85 mph speed points. To compensate for these errors, the changes in Table 5-9 were made to the compensation factors.

Table 5-9 – Calibration 1 Equipment Factor Changes – 02-Mar-11

Speed Points	Old Factors		Error	New Factors	
	Left	Right		Left	Right
	1	2		1	2
72	3422	3422	2.74%	3331	3331
88	3422	3422	3.42%	3309	3309
104	3422	3422	3.26%	3314	3314
120	3422	3422	3.26%	3314	3314
136	3422	3422	3.26%	3314	3314
Axle Distance (cm)	370		-0.34%	371	
Dynamic Comp (%)	103		-1.22%	104	
Loop Width (cm)	180		0.17 ft	185	

5.3 Calibration

5.3.1.1 Calibration 1 Results

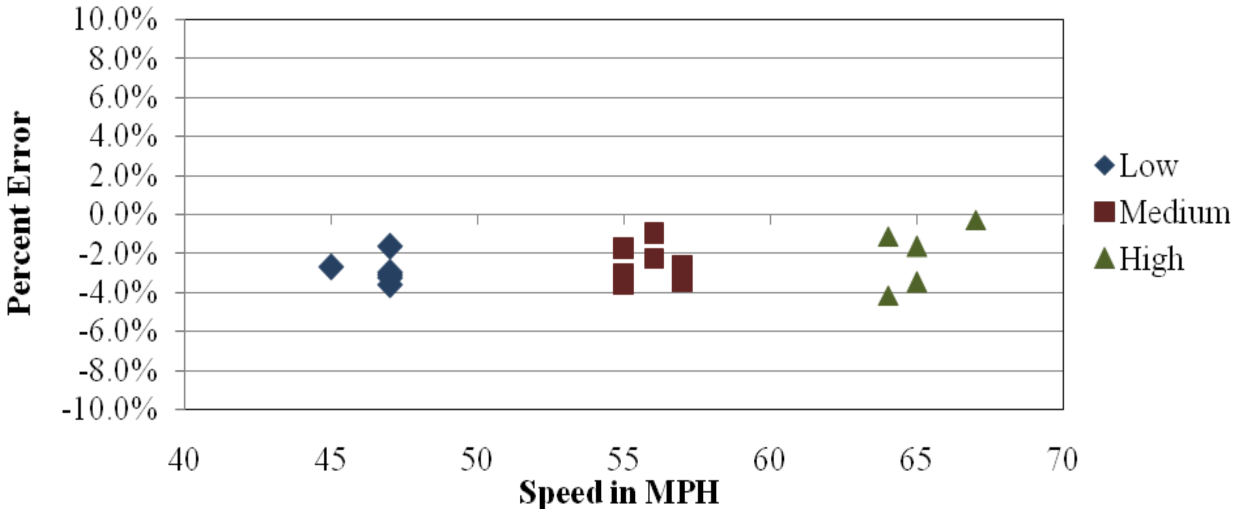
The results of the 18 first calibration verification runs are provided in Table 5-10 and Figure 5-11. As can be seen in the table, the mean error of all weight estimates was reduced as a result of the first calibration iteration.

Table 5-10 – Calibration 1 Results – 02-Mar-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-4.5 ± 4.9%	Pass
Tandem Axles	±15 percent	-2.1 ± 4.1%	Pass
GVW	±10 percent	-2.6 ± 2.3%	Pass
Vehicle Length	±3.0 percent (1.7 ft)	0.3 ± 1.2 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Figure 5-11 shows that the WIM equipment is estimating GVW with reasonable accuracy at all speeds.

Figure 5-11 – Calibration 1 GVW Error by Speed – 02-Mar-11



Based on the results of the first calibration, where weight estimate bias decreased to -2.6 percent, and GVW estimates were expected to increase with increases in temperature, a second calibration was not considered to be necessary. The 18 calibration runs were combined with 22 additional post-validation runs to complete the WIM system validation.

5.3 Post-Validation

The 40 post-validation test truck runs were conducted on March 02, 2011, beginning at approximately 7:53 AM and continuing until 1:06 PM.

The two test trucks consisted of:

- A Class 9 truck, loaded with stone, and equipped with air suspension on truck and trailer tandems and with standard tandem spacings on both the tractor and trailer.

- A Class 9, 5-axle truck, loaded with stone, and equipped with air suspension on the tractor, air suspension on the trailer, with standard tandem spacing on the tractor and standard tandem spacing on the trailer.

The test trucks were weighed prior to the post-validation and re-weighed at the conclusion of the post-validation. The average test truck weights and measurements are provided in Table 5-11.

Table 5-11 - Post-Validation Test Truck Measurements

Test Truck	Weights (kips)						Spacings (feet)					
	GVW	Ax1	Ax2	Ax3	Ax4	Ax5	1-2	2-3	3-4	4-5	AL	OL
1	75.4	9.4	16.1	16.1	16.9	16.9	15.0	4.3	29.3	4.4	53.0	59.0
2	65.9	10.2	12.1	12.1	15.8	15.8	14.1	4.3	23.8	4.3	46.4	52.7

Test truck speeds varied by 22 mph, from 45 to 67 mph. The measured post-validation pavement temperatures varied 43.6 degrees Fahrenheit, from 26.8 to 70.4. The sunny weather conditions provided attaining the desired minimum30 degree temperature range. Table 5-12 is a summary of post validation results.

Table 5-12 – Post-Validation Overall Results – 02-Mar-11

Parameter	95% Confidence Limit of Error	Site Values	Pass/Fail
Steering Axles	±20 percent	-2.0 ± 5.2%	Pass
Tandem Axles	±15 percent	-0.4 ± 5.1%	Pass
GVW	±10 percent	-0.7 ± 3.7%	Pass
Vehicle Length	±3.0 percent (1.7 ft)	0.1 ± 1.1 ft	Pass
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	Pass

Truck speed was manually collected for each test run using a radar gun and compared with the speed reported by the WIM equipment. For this site, the average error in speed measurement for all speeds was -0.5 ± 1.8 mph, which is greater than the ±1.0 mph tolerance established by the LTPP Field Guide. However, since the site is measuring axle spacing length with a mean error of 0.0, and the speed and axle spacing length measurements are based on the distance between the axle detector sensors, it can be concluded that the distance factor is set correctly and that the speeds being reported by the WIM equipment are within acceptable ranges.

5.3.1 Statistical Speed Analysis

Statistical analysis was conducted on the test truck run data to investigate whether a relationship exists between speed and WIM equipment weight and distance measurement accuracy. The posted speed limit at this site is 65 mph. The test runs were divided into three speed groups - low, medium and high speeds, as shown in Table 5-13.

Table 5-13 – Post-Validation Results by Speed – 02-Mar-11

Parameter	95% Confidence Limit of Error	Low	Medium	High
		45.0 to 52.3 mph	52.4 to 59.8 mph	59.9 to 67.0 mph
Steering Axles	+20 percent	-1.2 ± 6.8%	-1.5 ± 4.6%	-3.1 ± 4.3%
Tandem Axles	+15 percent	-0.4 ± 4.9%	-1.3 ± 4.5%	0.5 ± 6.3%
GVW	+10 percent	-0.6 ± 4.3%	-1.4 ± 3.1%	-0.2 ± 4.3%
Vehicle Length	±3.0 percent (1.7 ft)	0.1 ± 0.8 ft	0.2 ± 1.5 ft	0.1 ± 1.4 ft
Vehicle Speed	± 1.0 mph	-0.3 ± 2.7 mph	-0.7 ± 1.6 mph	-0.5 ± 1.1 mph
Axle Length	+ 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft	0.0 ± 0.1 ft

From the table, it can be seen that the WIM equipment estimates all weights with reasonable accuracy and the range of errors is consistent at all speeds. There does not appear to be a relationship between weight estimates and speed at this site.

To aid in the speed analysis, several graphs were developed to illustrate the possible effects of speed on GVW, single axle, and axle group weights, and axle and overall length distance measurements, as discussed in the following paragraphs.

5.3.1.1 GVW Errors by Speed

As shown in Figure 5-12, the equipment estimated GVW with reasonable accuracy at all speeds. The range in error and bias is similar throughout the entire speed range.

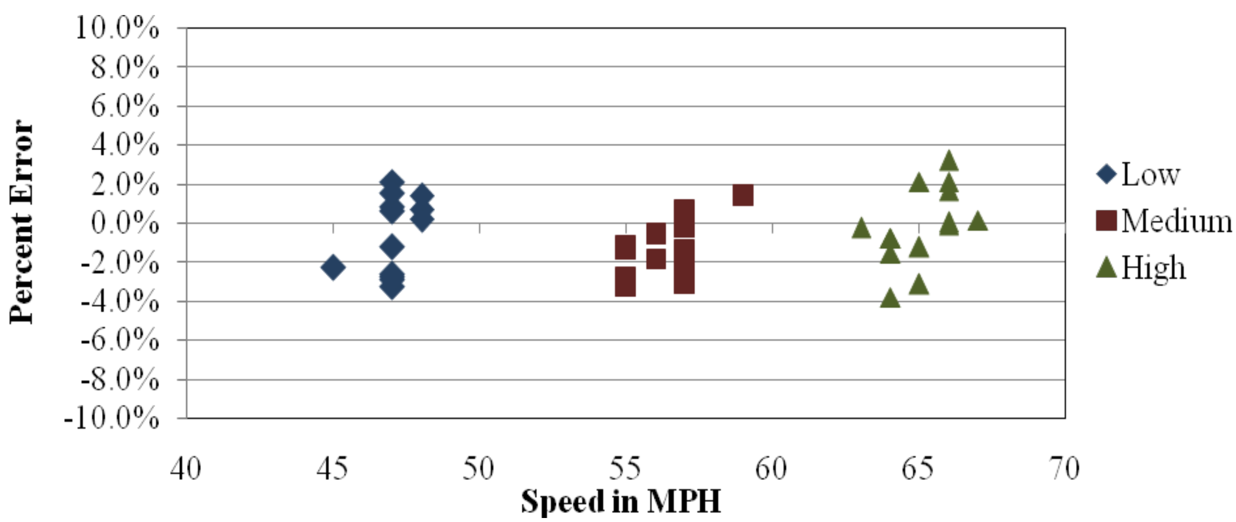


Figure 5-12 – Post-Validation GVW Errors by Speed – 02-Mar-11

5.3.1.2 Steering Axle Weight Errors by Speed

As shown in Figure 5-13, the equipment estimated steering axle weights with reasonable accuracy at all speeds. However, the estimation of steering axle weight appears to decrease as speed increases. The range in error is similar throughout the entire speed range. There does appear to be a slight correlation between speed and steering axle weight estimates at this site, where estimates decrease as speed increases.

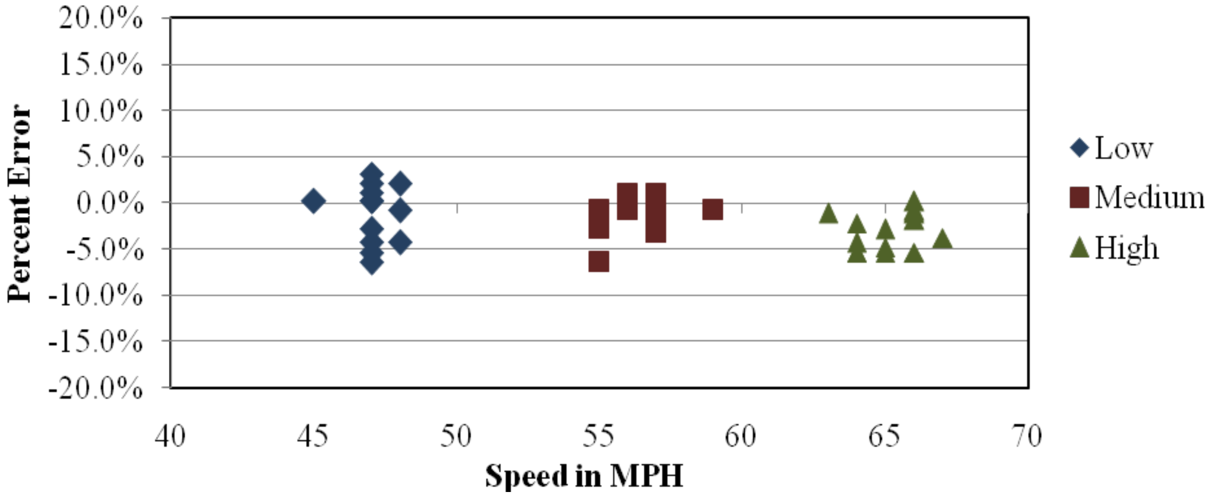


Figure 5-13 – Post-Validation Steering Axle Weight Errors by Speed – 02-Mar-11

5.3.1.3 Tandem Axle Weight Errors by Speed

As shown in Figure 5-14, the equipment estimated tandem axle weights with reasonable accuracy at all speeds. The range in error and bias is similar throughout the entire speed range.

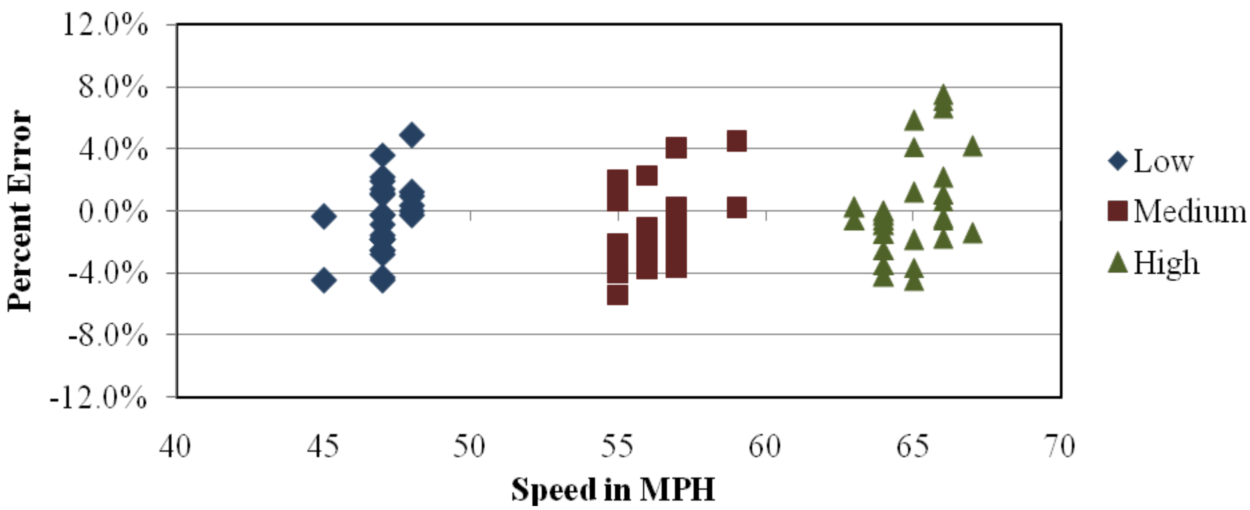


Figure 5-14 – Post-Validation Tandem Axle Weight Errors by Speed – 02-Mar-11

5.3.1.4 GVW Errors by Speed and Truck Type

It can be seen in Figure 5-15 that when the GVW errors are analyzed by truck type, the WIM equipment precision and bias is similar for both the heavily loaded (Primary) truck and the partially loaded (Secondary) truck at the low and medium speeds. At the higher speeds GVW is generally overestimated for the Secondary truck and underestimated for the Primary truck.

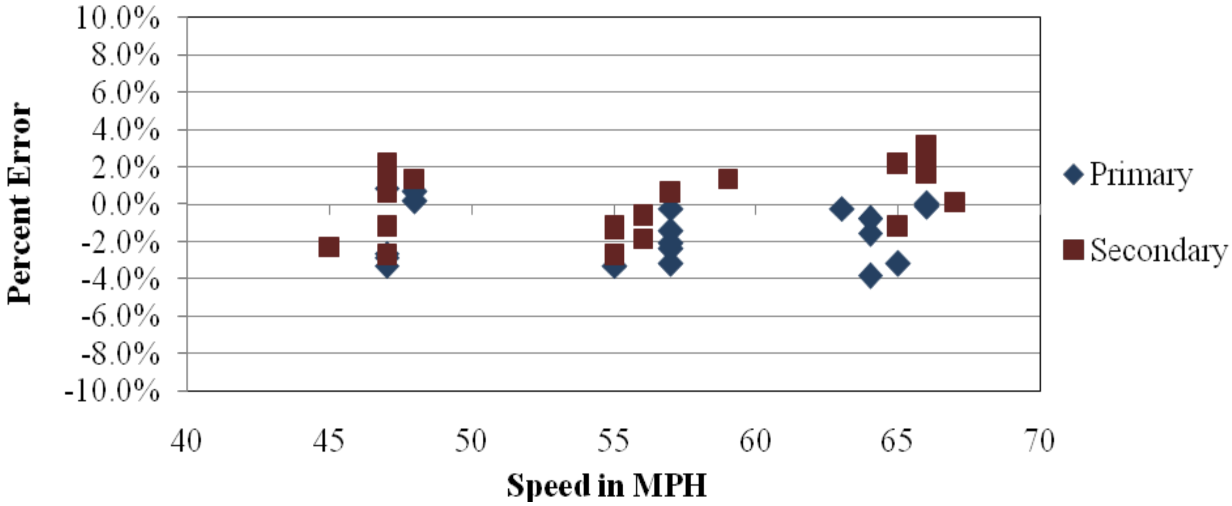


Figure 5-15 – Post-Validation GVW Error by Truck and Speed – 02-Mar-11

5.3.1.5 Axle Length Errors by Speed

For this site, the error in axle length measurement was consistent at all speeds. The range in axle length measurement error ranged from 0.0 feet to 0.1 feet. Distribution of errors is shown graphically in Figure 5-16.

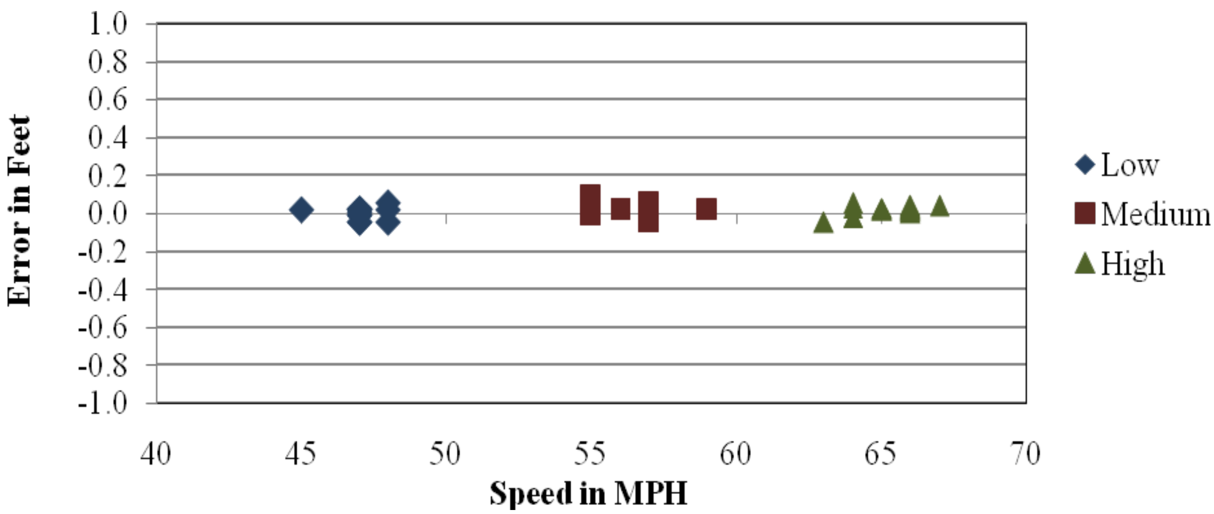


Figure 5-16 – Post-Validation Axle Length Error by Speed – 02-Mar-11

5.3.1.6 Overall Length Errors by Speed

For this system, the WIM equipment measures overall length consistently over the entire range of speeds, with errors ranging from -1.0 to 1.3 feet. Distribution of errors is shown graphically in Figure 5-17.

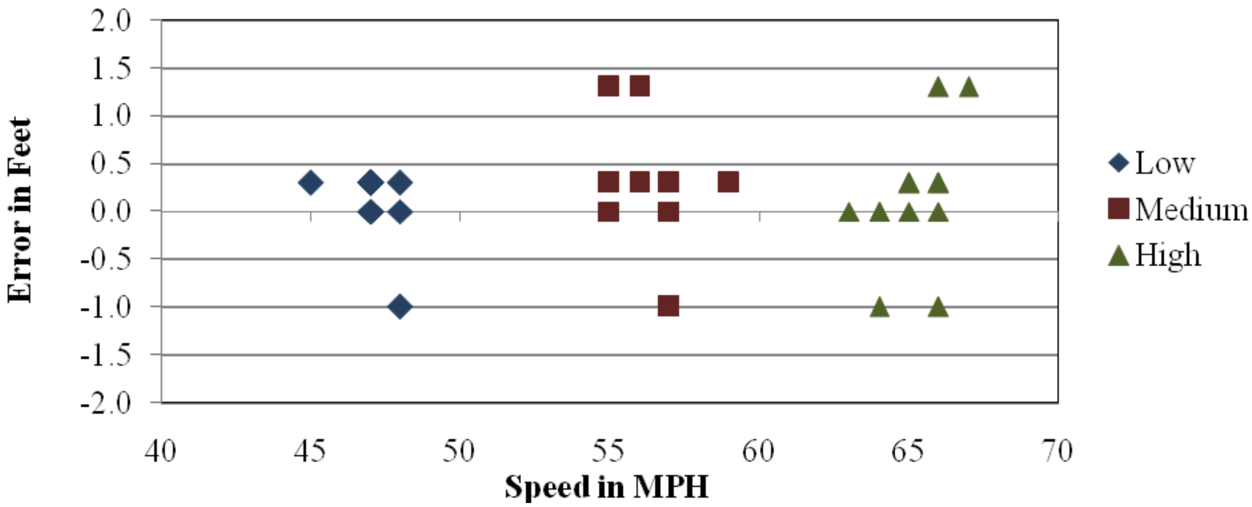


Figure 5-17 – Post-Validation Overall Length Error by Speed – 02-Mar-11

5.3.2 Statistical Temperature Analysis

Statistical analysis was performed for the test truck run data to investigate whether a relationship exists between pavement temperature and WIM equipment weight and distance measurement accuracy. The range of pavement temperatures was 43.6 degrees, from 26.8 to 70.4 degrees Fahrenheit. The post-validation test runs are reported under three temperature groups – low, medium and high, as shown in Table 5-14 below.

Table 5-14 – Post-Validation Results by Temperature – 02-Mar-11

Parameter	95% Confidence Limit of Error	Low	Medium	High
		26.8 to 41.3 degF	41.4 to 56.0 degF	56.1 to 70.4 degF
Steering Axles	±20 percent	-3.2 ± 6.0%	-1.7 ± 5.7%	-1.3 ± 4.7%
Tandem Axles	±15 percent	-2.5 ± 3.1%	-0.4 ± 4.8%	1.2 ± 4.4%
GVW	±10 percent	-2.6 ± 1.8%	-0.7 ± 2.9%	0.7 ± 2.8%
Vehicle Length	±3.0 percent (1.7 ft)	0.2 ± 0.8 ft	0.3 ± 1.5 ft	-0.1 ± 1.2 ft
Vehicle Speed	± 1.0 mph	-0.8 ± 2.1 mph	-0.5 ± 1.8 mph	-0.3 ± 1.9 mph
Axle Length	± 0.5 ft [150mm]	0.0 ± 0.1 ft	0.0 ± 0.1 ft	0.0 ± 0.1 ft

To aid in the analysis, several graphs were developed to illustrate the possible effects of temperature on GVW, single axle weights, and axle group weights.

5.3.2.1 GVW Errors by Temperature

From Figure 5-18, it can be seen that the equipment appears to estimate GVW with acceptable accuracy across the range of temperatures observed in the field. There does appear to be a correlation between temperature and weight estimates at this site where estimation of GVW appears to increase as temperature increases.

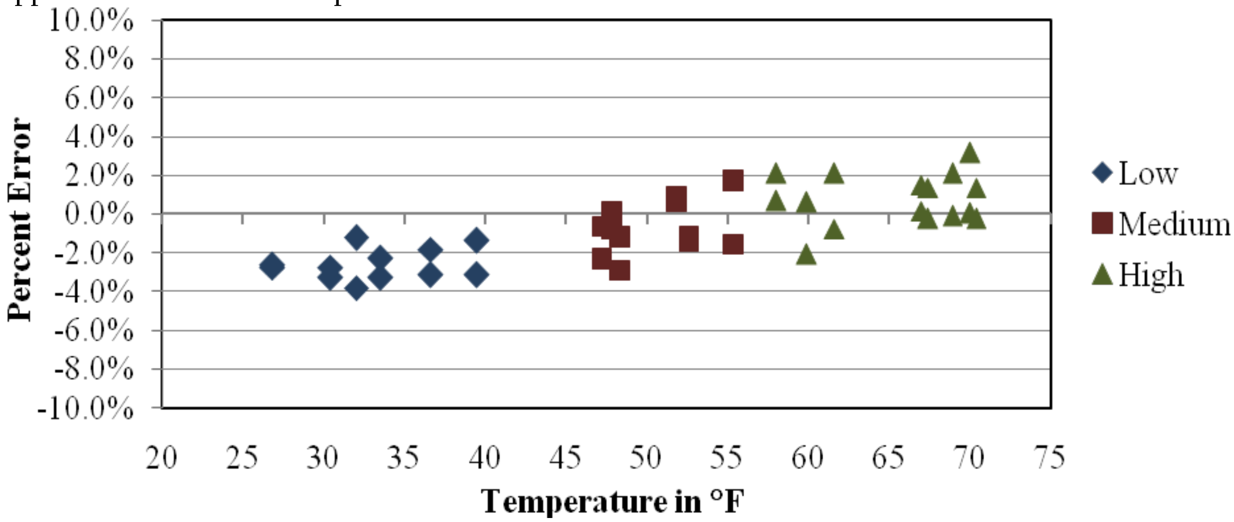


Figure 5-18 – Post-Validation GVW Errors by Temperature – 02-Mar-11

5.3.2.2 Steering Axle Weight Errors by Temperature

Figure 5-19 demonstrates that for steering axles, the WIM equipment appears to underestimate weights with similar accuracy across the range of temperatures observed in the field. There does not appear to be a correlation between temperature and steering axle weight estimates at this site. The range in error is similar for different temperature groups.

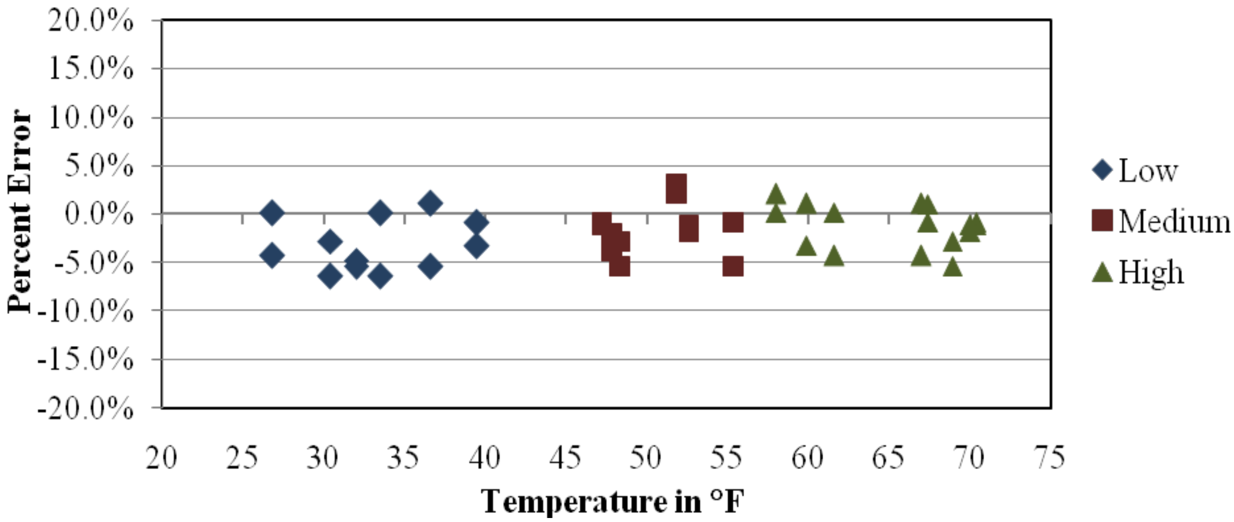


Figure 5-19 – Post-Validation Steering Axle Weight Errors by Temperature – 02-Mar-11

5.3.2.3 Tandem Axle Weight Errors by Temperature

As shown in Figure 5-20, the WIM equipment appears to estimate tandem axle weights with acceptable accuracy across the range of temperatures observed in the field. There does appear to be a correlation between temperature and tandem axle weight estimates at this site where estimation of tandem axle weights increases as temperature increases. The range in tandem axle weight errors is consistent for the three temperature groups.

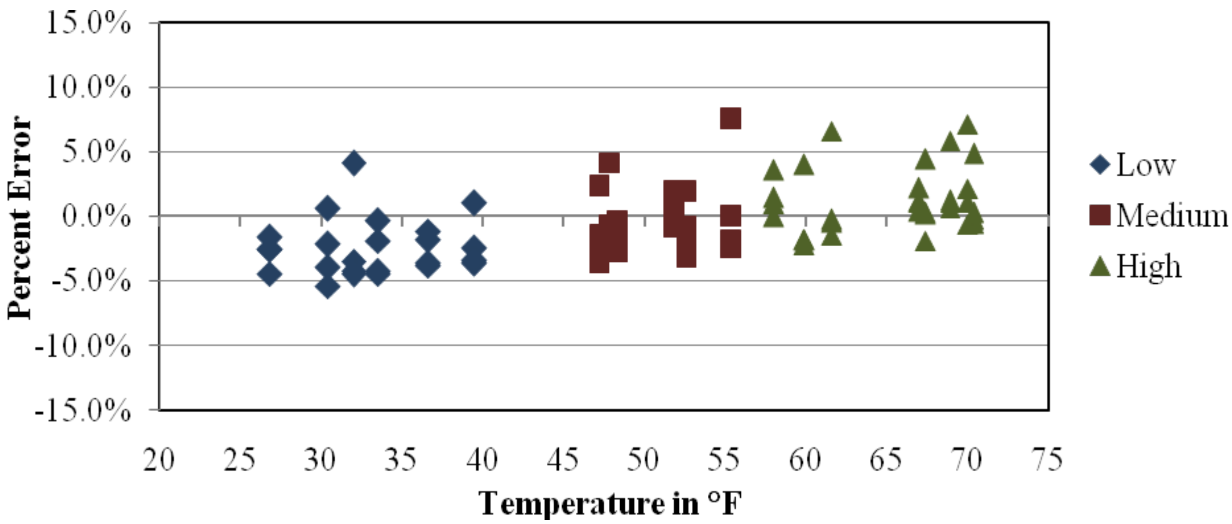


Figure 5-20 – Post-Validation Tandem Axle Weight Errors by Temperature – 02-Mar-11

5.3.2.4 GVW Errors by Temperature and Truck Type

As shown in Figure 5-21, when analyzed by truck type, GVW measurement error patterns for both trucks are similar at all temperatures. For both trucks, the range of errors and bias are reasonably consistent over the range of temperatures. As observed before, the GVW error increases with temperature. In general, the errors for GVW of the Secondary truck are slightly higher than the corresponding errors for the Primary truck.

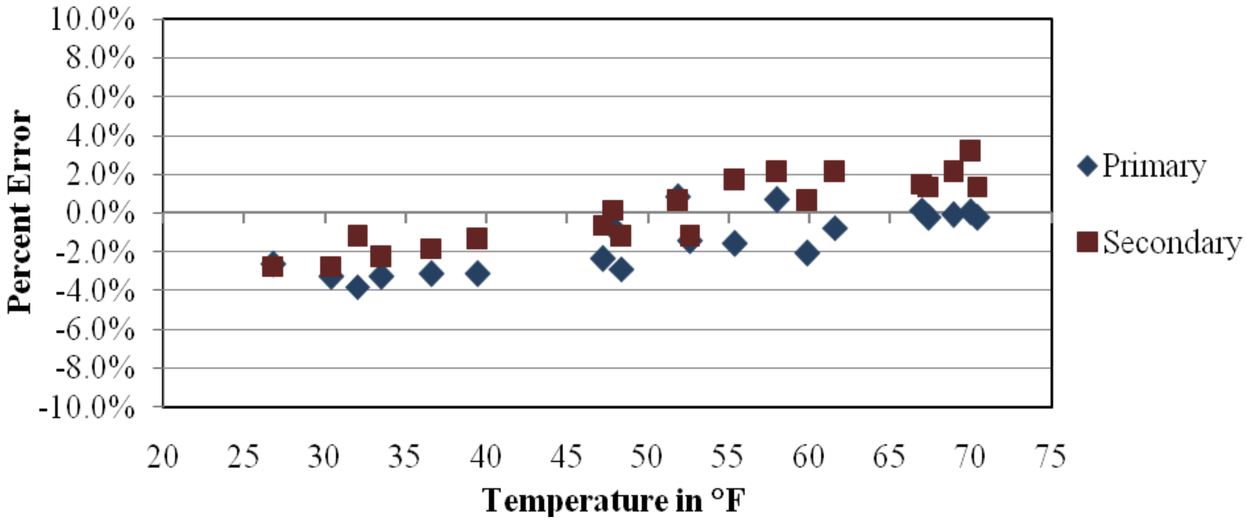


Figure 5-21 – Post-Validation GVW Error by Truck and Temperature – 02-Mar-11

5.3.3 GVW and Steering Axle Trends

Figure 5-22 is provided to illustrate the predicted GVW error with respect to the post-validation errors by speed.

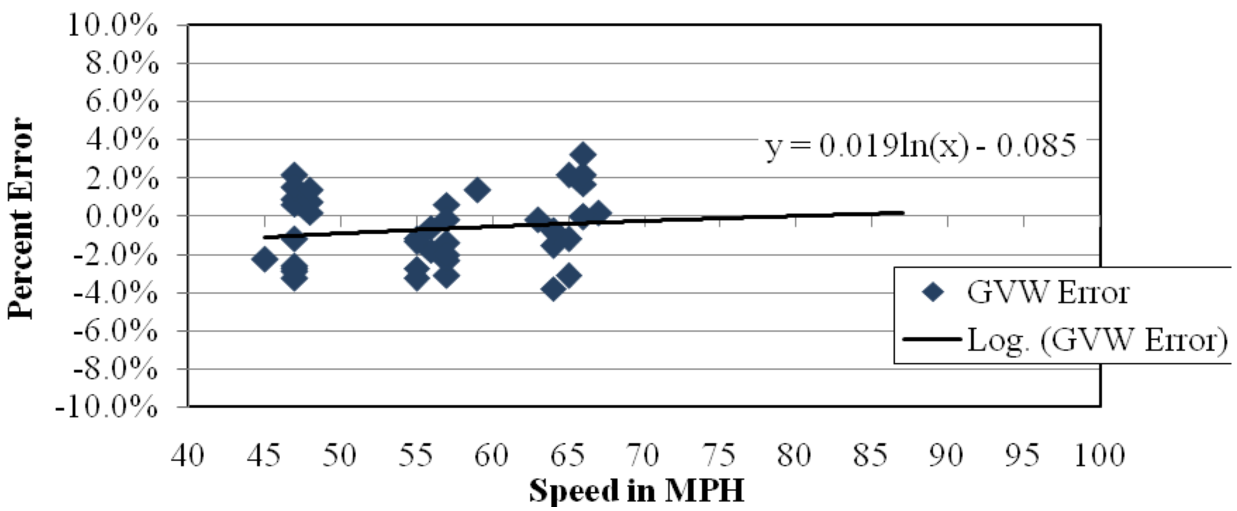


Figure 5-22 - GVW Error Trend by Speed

Figure 5-23 is provided to illustrate the predicted Steering Axle error with respect to the post-validation errors by speed.

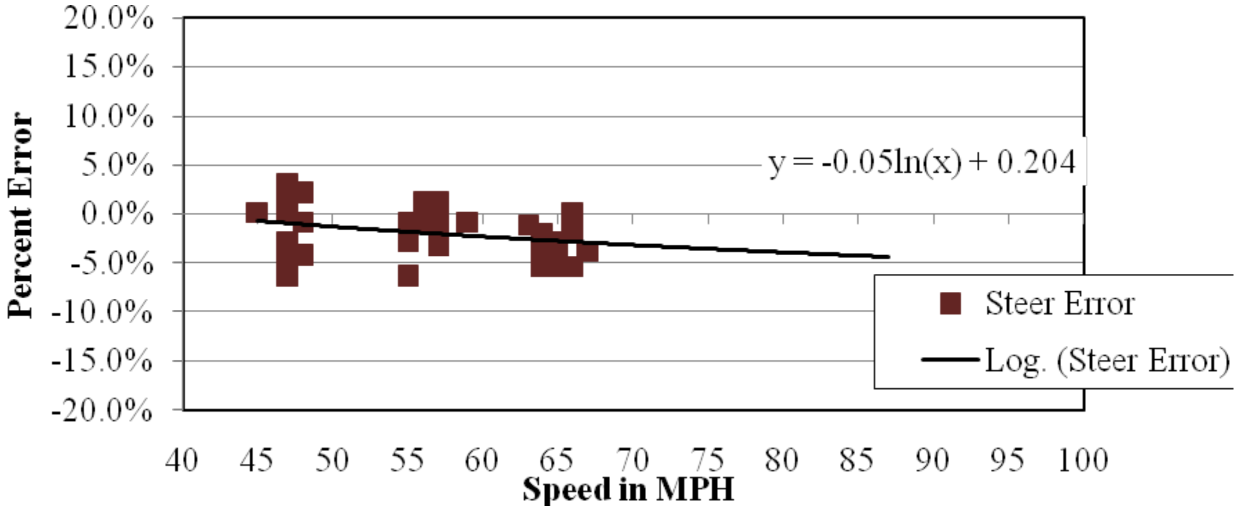


Figure 5-23 - Steering Axle Trend by Speed

5.3.4 Multivariable Analysis

This section provides additional analysis of post-validation results using a multivariable statistical technique of multiple linear regression. The same calibration data analyzed and discussed previously are analyzed again, but this time using a more sophisticated statistical methodology. The objective of the additional analysis is to investigate if the trends identified using previous analyses are statistically significant, and to quantify these trends.

Multivariable analyses provide additional insight on how speed, temperature, and truck type affect weight measurement errors for a specific site. It is expected that multivariable analyses done systematically for many sites will reveal overall trends.

5.3.4.1 Data

All errors from the weight measurement data collected by the equipment during the validation were analyzed. The percent error is defined as percentage difference between the weight measured by the WIM system and the static weight. Compared to analysis described previously, the weight of "axle group" was evaluated separately for tandem axles on tractors and on trailers. The separate evaluation was carried out because the tandem axles on trailers may have different dynamic response to loads than tandem axles on tractors.

The measurement errors were statistically attributed to the following variables or factors:

- Truck type. Primary truck and secondary truck.
- Truck test speed. Truck test speed ranged from 45 to 67 mph.
- Pavement temperature. Pavement temperature ranged from 26.8 to 70.4 degrees Fahrenheit.

- Interaction between the factors such as the interaction between speed and pavement temperature.

5.3.4.2 Results

For analysis of GVW weights, the value of regression coefficients and their statistical properties are summarized in Table 5-15. The value of regression coefficients defines the slope of the relationship between the % error in GVW and the predictor variables (speed, temperature, and truck type). The values of the t-distribution (for the regression coefficients) given in Table 5-15 are for the null hypothesis that assumes that the coefficients are equal to zero. The effect of temperature truck type was found to be statistically significant. For example, the probability that the effect of truck type on the observed GVW errors occurred by chance alone was less than 1 percent.

Table 5-15 – Table of Regression Coefficients for Measurement Error of GVW

Parameter	Regression coefficients	Standard error	Value of t-distribution	Probability value
Intercept	-6.7439	1.1020	-6.1199	0.0000
Speed	0.0016	0.0190	0.0863	0.9317
Temp	0.1006	0.0101	9.9147	0.0000
Truck	1.5781	0.2757	5.7246	0.0000

The relationship between temperature and measurement errors is shown in Figure 5-24. The figure includes trend line for the predicted percent error. Besides the visual assessment of the relationship, Figure 5-24 provides quantification and statistical assessment of the relationship.

The quantification is provided by the value of the regression coefficient, in this case 0.1006 (in Table 5-15). This means, for example, that for a 20 degree increase in temperature, the % error is increased by about 2.0 % (0.1006 x 20). The statistical assessment of the relationship is provided by the probability value of the regression coefficient.

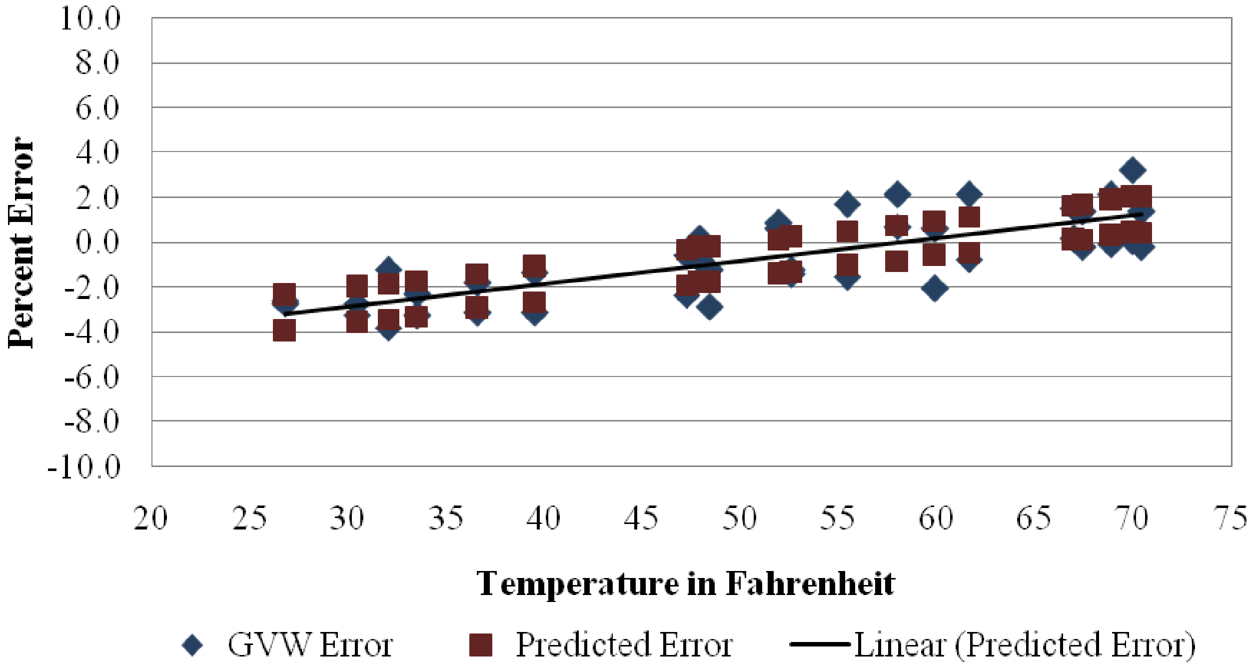


Figure 5-24 – Influence of Temperature on the Measurement Error of GVW

The effect of speed on GVW was not statistically significant. The probability that the regression coefficient for speed (-0.0016 in Table 5-15) is not different from zero was 0.9317. In other words, there is about 93 percent chance that the value of the regression coefficient is due to the chance alone.

The interaction between speed, temperature, and truck type was investigated by adding an interactive variable (or variables) such as the product of speed and temperature. No interactive variables were statistically significant..

5.3.4.3 Summary Results

Table 5-16 lists regression coefficients and their probability values for all combinations of factors and % errors evaluated. Not listed in the table are factor interactions because the interactions were not statistically significant. Entries in the table are provided only if the probability value was smaller than 0.20. The dash in Table 5-16 indicates that the relationship was not statistically significant (the probability that the relationship can occur by chance alone was greater than 20 percent).

Table 5-16 – Summary of Regression Analysis

	Factor					
	Speed		Temperature		Truck type	
Weight, % error	Regression coefficient	Probability value	Regression coefficient	Probability value	Regression coefficient	Probability value
GVW	-	-	0.1006	0.0000	1.5781	0.0000
Steering axle	-0.1222	0.0122	0.0680	0.0091	1.8978	0.0075
Tandem axle tractor	0.0930	0.0067	0.0893	0.0000	4.2917	0.0000
Tandem axle trailer	-0.0307	0.1929	0.1295	0.0000	-	-

5.3.4.4 Conclusions

1. Speed had statistically significant effect on measurement errors of steering and tandem axles, but did not have statistically significant effect on the measurement errors of GVW. Based on the signs of the regression coefficients, the effect of speed was both positive (for tandem axles on tractors) and negative for steering axles and tandem axles on trailers).

2. Temperature affected measurement error of all axles and thus also the measurement error of the GVW. The regression coefficients ranged from 0.1295 for the tandem axles on trailers to 0.68 for the steering axels . The difference between regression coefficients obtained for different axle types and GVW was not statistically significant.

3. Truck type affected the GVW, steering axle weight, and the tandem axle tractor weight errors. The regression coefficient for truck type in Table 5-16, represent the difference between the mean errors for the primary and secondary trucks. (Truck type is an indicator variable with values of 0 or 1.). For example, the mean error in GVW for the secondary truck was about 1.6 % larger than the mean error for the primary truck.

4. Even though temperature and truck type had statistically significant effect on measurement errors, the practical significance of these factors is small and does not affect the validity of the calibration.

5.3.5 Classification and Speed Evaluation

The post-validation classification and speed study involved the comparison of vehicle classification and speed data collected manually with the information for the same vehicles reported by the WIM equipment.

For the post-validation classification study at this site, a manual sample of 100 vehicles including 100 trucks (Class 4 through 13) was collected. Video was collected during the study to provide a means for further analysis of misclassifications and vehicles whose classifications could not be determined with a high degree of certainty in the field. Table 5-17 illustrates the breakdown of vehicles observed and identified by the WIM equipment for the manual classification study.

Table 5-17 – Post-Validation Classification Study Results – 02-Mar-11

Class	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Observed Count	1	17	16	3	2	56	0	5	0	0
WIM Count	0	15	16	2	4	57	0	5	0	0
Observed Percent	1.0	17.0	16.0	3.0	2.0	56.0	0.0	5.0	0.0	0.0
WIM Percent	0.0	15.0	16.0	2.0	4.0	57.0	0.0	5.0	0.0	0.0
Misclassified Count	1	3	0	0	0	0	0	0	0	0
Misclassified Percent	100.0	17.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Unclassified Count	0	0	0	1	0	0	0	0	0	0
Unclassified Percent	0.0	0.0	0.0	50.0	0.0	0.0	0.0	0.0	0.0	0.0

Misclassified vehicles are defined as those vehicles that are manually classified by observation as one type of vehicle but identified by the WIM equipment as another type of vehicle. For this site, four vehicles were misclassified and one vehicle was unclassified by the equipment. The misclassifications by pair are provided in Table 5-18.

Table 5-18 – Post-Validation Misclassifications by Pair – 02-Mar-11

Observed/ WIM	**Number of Pairs**	**Observed/ WIM**	**Number of Pairs**	**Observed/ WIM**	**Number of Pairs**
4/5	1	6/7	0	9/8	0
4/6	0	6/8	0	9/10	0
5/3	0	6/9	0	10/9	0
5/4	0	6/10	0	10/13	0
5/6	0	7/6	0	11/12	0
5/7	0	8/3	0	12/11	0
5/8	2	8/5	0	13/10	0
5/9	1	8/9	0	13/11	0
6/4	0	9/5	0		

Based on the vehicles observed during the post-validation study, the misclassification percentage is 0.0% for heavy trucks (6 – 13), which is within the 2.0% acceptability criteria for LTPP SPS WIM sites. The overall misclassification rate for all vehicles (4 – 15) is 4.0%.

As shown in the table, a total of 4 vehicles, including no heavy trucks (6 – 13) were misclassified by the equipment. The misclassifications consisted of 1 Class 4 identified as a Class 5, two Class

5s identified as Class 8s, and one Class 5 identified as a Class 9. The reasons for the misclassifications were not determined in the field.

Unclassified vehicles are defined as those vehicles that cannot be identified by the WIM equipment algorithm. These are typically trucks with unusual trailer tandem configurations and are identified as Class 15 by the WIM equipment. The unclassified vehicles by pair are provided in Table 5-19.

Table 5-19 – Post-Validation Unclassified Trucks by Pair – 02-Mar-11

Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs	Observed/ WIM	Number of Pairs
3/15	0	7/15	1	11/15	0
4/15	0	8/15	0	12/15	0
5/15	0	9/15	0	13/15	0
6/15	0	10/15	0		

Based on the manually collected sample of the 100 trucks, 1.0% of the vehicles at this site were reported as unclassified during the study. This is within the established criteria of 2.0% for LTTP SPS WIM sites. The unclassified vehicles were a single Class 7 which could not be identified by the WIM equipment. The cause of the un-classification was not investigated in the field.

For speed, the mean error for WIM equipment speed measurement was -0.4 mph; the range of errors was 0.9 mph.

Based on these findings, it is recommended that an expanded investigation focusing on vehicle classification issues indicated in this report be conducted. The study shall focus on the identification of the cause for the misclassifications and the development of recommendations to remedy these causes. This study may be conducted in conjunction with the next calibration and validation visit.

6 Previous WIM Site Validation Information

The information reported in this section provides a summary of the performance of the WIM equipment since it was installed or since the first validation was performed on the equipment. The information includes historical data on weight and classification accuracies as well as a comparison of post-validation results.

6.1 Sheet 16s

This site has validation information from three previous visits as well as the current one as summarized in the tables below and provided on the Traffic Sheet 16. Table 6-1 data was extracted from the most recent previous validation and was updated to include the results of this validation.

Table 6-1 – Classification Validation History

Date	Misclassification Percentage by Class										Pct Unclass
	4	5	6	7	8	9	10	11	12	13	
30-Jan-07	N/A	0	0	N/A	0	0	N/A	0	N/A	N/A	0
24-Jul-07	N/A	0	0	N/A	0	0	0	0	0	N/A	0
25-Jul-07	N/A	0	0	N/A	0	0	0	0	0	N/A	0
2-Dec-08	N/A	0	0	N/A	0	0	N/A	0	N/A	N/A	0
4-Dec-08	100	0	9	N/A	0	0	N/A	N/A	N/A	0	0
1-Mar-11	100	5	17	0	0	0	0	0	0	0	1
2-Mar-11	100	18	0	0	0	0	0	0	0	0	1

Table 6-2 data was extracted from the previous validation and was updated to include the results of this validation. The table provides the mean error and standard deviation for GVW, single axles and tandems for prior pre- and post-validations as reported on the LTPP Traffic Sheet 16s.

Table 6-2 – Weight Validation History

Date	Mean Error and SD		
	GVW	Single Axles	Tandem
30-Jan-07	0.7 ± 2.7	-2.6 ± 3.2	1.3 ± 3.5
1-Feb-07	-0.8 ± 2.7	-4.7 ± 2.6	-0.1 ± 3.6
24-Jul-07	-0.4 ± 3.1	-0.5 ± 4.2	0.4 ± 5.5
25-Jul-07	0.1 ± 3.0	-2.7 ± 5.1	0.9 ± 4.5
2-Dec-08	4.2 ± 1.3	0.8 ± 2.3	5.1 ± 2.9
4-Dec-08	1.0 ± 1.6	1.5 ± 2.5	1.2 ± 2.9
1-Mar-11	3.1 ± 1.7	1.8 ± 3.8	3.5 ± 2.2
2-Mar-11	-0.7 ± 1.8	-2.0 ± 2.6	-0.4 ± 2.5

The variability of the weight errors appears to have remained reasonably consistent since the site was first validated. From this information, it appears that the system demonstrates a tendency for the equipment to move toward an overestimation of GVW over time. The table also demonstrates the effectiveness of the validations in bringing the weight estimations within LTPP SPS WIM equipment tolerances.

6.2 Comparison of Past Validation Results

A comparison of the post-validation results from previous visits is provided in Table 6-3. The table provides the historical performance of the WIM system with regard to the 95% confidence interval tolerances.

Table 6-3 – Comparison of Post-Validation Results

Parameter	95 %Confidence Limit of Error	Site Values (Mean Error and 95% Confidence Interval)			
		2-Dec-08	24-Jul-07	30-Jan-07	2-Mar-11
Steering Axles	±20 percent	0.8 ± 4.7	-0.5 ± 8.4	-2.6 ± 6.4	-2 ± 5.2
Tandem Axles	±15 percent	5.1 ± 5.7	0.4 ± 10.9	1.3 ± 6.9	-0.4 ± 5.1
GVW	±10 percent	4.2 ± 2.7	-0.4 ± 6.2	0.7 ± 5.4	-0.7 ± 3.7

From Table 6-3, it appears that the mean error and the 95% confidence interval has remained reasonably consistent for all weights since the equipment was installed, with the possible exception of the July 24, 2007 validation, where some of the 95% confidence intervals were slightly increased.

The final factors left in place at the conclusion of the validation are provided in Table 6-4.

Table 6-4 – Final Factors

Speed Point	MPH	Left	Right
		1	2
72	45	3331	3331
88	55	3309	3309
104	65	3314	3314
120	75	3314	3314
136	85	3314	3314
Axle Distance (cm)	371		
Dynamic Comp (%)	104		
Loop Width (cm)	185		

A review of the LTPP Standard Release Database 24 shows that there are 2 years of level “E” WIM data for this site. This site requires 3 additional years of data to meet the minimum of five years of research quality data.

7 Additional Information

The following information is provided in the attached appendix:

- Site Photographs
    - Equipment
    - Test Trucks
    - Pavement Condition
- Pre-validation Sheet 16 – Site Calibration Summary
- Post-validation Sheet 16 – Site Calibration Summary
- Pre-validation Sheet 20 – Classification and Speed Study
- Post-validation Sheet 20 – Classification and Speed Study

Additional information is available upon request through LTPP INFO at ltppinfo@dot.gov, or telephone (202) 493-3035. This information includes:

- Sheet 17 – WIM Site Inventory
- Sheet 18 – WIM Site Coordination
- Sheet 19 – Validation Test Truck Data
- Sheet 21 – WIM System Truck Records
- Sheet 22 – Site Equipment Assessment plus Addendum
- Sheet 24A/B – Site Photograph Logs
- Updated Handout Guide

WIM System Field Calibration and Validation - Photos

Virginia, SPS-1
SHRP ID: 510100

Validation Date: March 1, 2011

APPLIED RESEARCH ASSOCIATES, INC.

Photo 1 – Cabinet Exterior

Photo 2 – Cabinet Interior (Front)

Photo 3 – Cabinet Interior (Back)

Photo 4 – Leading Loop

Photo 5 – Leading WIM Sensor

Photo 6 – Trailing WIM Sensor

Photo 7 – Trailing Loop Sensor

Photo 8 – Power Service Box

Photo 9 – Telephone Service Box

Photo 10 – Downstream

Photo 11 – Upstream

Photo 12 – Truck 1

Photo 13 – Truck 1 Tractor

Photo 14 – Truck 1 Trailer and Load

Photo 15 – Truck 1 Suspension 1

Photo 16 – Truck 1 Suspension 2

Photo 17 – Truck 1 Suspension 3

Photo 18 – Truck 1 Suspension 4

Photo 19 – Truck 1 Suspension 5

Photo 20 – Truck 2

Photo 21 – Truck 2 Tractor

Photo 22 – Truck 2 Trailer and Load

Photo 23 – Truck 2 Suspension 1

Photo 24 – Truck 2 Suspension 2

Photo 25 – Truck 2 Suspension 3

Photo 26 – Truck 2 Suspension 4

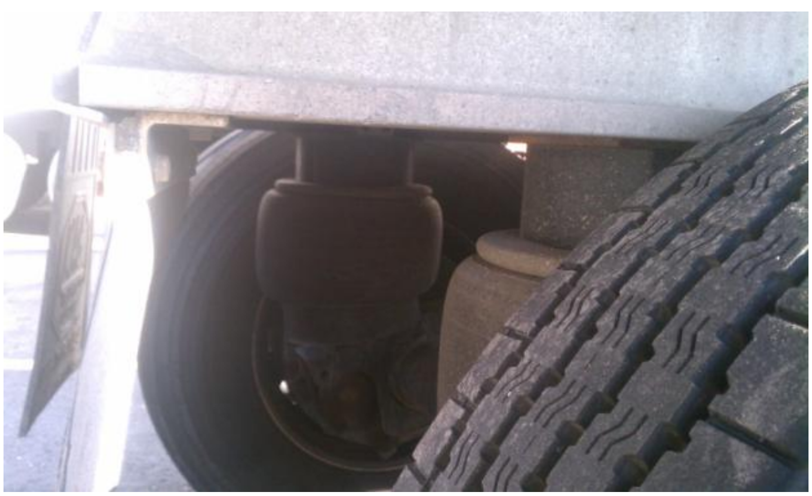


Photo 27 – Truck 2 Suspension 5

Traffic Sheet 16	STATE CODE:	51
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	510100
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	3/1/2011

SITE CALIBRATION INFORMATION

1. **DATE OF CALIBRATION** {mm/dd/yy} 3/1/11

2. **TYPE OF EQUIPMENT CALIBRATED:** Both

3. **REASON FOR CALIBRATION:** LTPP Validation

4. **SENSORS INSTALLED IN LTPP LANE AT THIS SITE** (Select all that apply):
   a. Inductance Loops
   b. Bending Plates
   c.
   d.

5. **EQUIPMENT MANUFACTURER:** IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

6. **CALIBRATION TECHNIQUE USED:** Test Trucks

Number of Trucks Compared:
Number of Test Trucks Used: 2
Passes Per Truck: 20

	Type	Drive Suspension	Trailer Suspension
Truck 1:	9	air	air
Truck 2:	9	air	air
Truck 3:			

7. **SUMMARY CALIBRATION RESULTS** (expressed as a %):

Mean Difference Between -

Dynamic and Static GVW:	3.1%	Standard Deviation:	1.7%
Dynamic and Static Single Axle:	1.8%	Standard Deviation:	3.8%
Dynamic and Static Double Axles:	3.5%	Standard Deviation:	2.2%

8. **NUMBER OF SPEEDS AT WHICH CALIBRATION WAS PERFORMED:** 3

9. **DEFINE SPEED RANGES IN MPH:**

			Low		High	Runs
a.	Low	-	44.0	to	52.0	13
b.	Medium	-	52.1	to	60.1	17
c.	High	-	60.2	to	68.0	10
d.		-		to		
e.		-		to		

Traffic Sheet 16	STATE CODE:	51
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	510100
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	3/1/2011

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3314 | 3314

11. IS AUTO- CALIBRATION USED AT THIS SITE? No

If yes , define auto-calibration value(s):

CLASSIFIER TEST SPECIFICS

12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:

Manual

13. METHOD TO DETERMINE LENGTH OF COUNT: Number of Trucks

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	2.0	FHWA Class	5	-	0.0
FHWA Class 8:	0.0	FHWA Class		-	
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 1.0%

Validation Test Truck Run Set - Pre

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 16	STATE CODE:	51
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	510100
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	3/2/2011

SITE CALIBRATION INFORMATION

1. DATE OF CALIBRATION {mm/dd/yy} 3/2/11

2. TYPE OF EQUIPMENT CALIBRATED: Both

3. REASON FOR CALIBRATION: LTPP Validation

4. SENSORS INSTALLED IN LTPP LANE AT THIS SITE (Select all that apply):

a. Inductance Loops
c.
b. Bending Plates
d.

5. EQUIPMENT MANUFACTURER: IRD iSINC

WIM SYSTEM CALIBRATION SPECIFICS

6. CALIBRATION TECHNIQUE USED: Test Trucks

Number of Trucks Compared:
Number of Test Trucks Used: 2
Passes Per Truck: 20

	Type	Drive Suspension	Trailer Suspension
Truck 1:	9	air	air
Truck 2:	9	air	air
Truck 3:			

7. SUMMARY CALIBRATION RESULTS (expressed as a %):

Mean Difference Between -

Dynamic and Static GVW:	-0.7%	Standard Deviation:	1.8%
Dynamic and Static Single Axle:	-2.0%	Standard Deviation:	2.6%
Dynamic and Static Double Axles:	-0.4%	Standard Deviation:	2.5%

8. NUMBER OF SPEEDS AT WHICH CALIBRATION WAS PERFORMED: 3

9. DEFINE SPEED RANGES IN MPH:

			Low		High	Runs
a.	Low	-	45.0	to	52.3	13
b.	Medium	-	52.4	to	59.8	13
c.	High	-	59.9	to	67.0	14
d.		-		to		
e.		-		to		

Traffic Sheet 16	STATE CODE:	51
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	510100
SITE CALIBRATION SUMMARY	DATE (mm/dd/yyyy)	3/2/2011

10. CALIBRATION FACTOR (AT EXPECTED FREE FLOW SPEED) 3315 | 3315

11. IS AUTO- CALIBRATION USED AT THIS SITE? No

If yes , define auto-calibration value(s):

CLASSIFIER TEST SPECIFICS

12. METHOD FOR COLLECTING INDEPENDENT VOLUME MEASUREMENT BY VEHICLE CLASS:

Manual

13. METHOD TO DETERMINE LENGTH OF COUNT: Number of Trucks

14. MEAN DIFFERENCE IN VOLUMES BY VEHICLES CLASSIFICATION:

FHWA Class 9:	2.0	FHWA Class	5	-	-12.0
FHWA Class 8:	100.0	FHWA Class	7	-	100.0
		FHWA Class		-	
		FHWA Class		-	

Percent of "Unclassified" Vehicles: 1.0%

Validation Test Truck Run Set - Post

Person Leading Calibration Effort: **Dean Wolf**

Contact Information: Phone: 717-975-3550

E-mail: dwolf@ara.com

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 51 SPS WIM ID: 510100 DATE (mm/dd/yyyy) 3/1/2011

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
64	9	607	64	9	64	9	946	65	9
62	9	608	64	9	67	6	949	65	6
57	5	610	57	5	65	9	971	66	9
70	6	614	70	6	66	5	975	66	5
65	12	659	63	12	65	9	976	66	9
70	**13**	**663**	**71**	**11**	63	5	1012	65	5
57	5	665	57	5	62	9	1016	62	9
57	9	666	57	9	64	5	1018	67	5
59	9	761	60	9	68	9	1027	70	9
70	9	768	65	9	65	9	1033	65	9
55	**5**	**772**	**55**	**4**	66	9	1045	65	9
64	9	777	65	9	62	9	1047	64	9
62	9	780	63	9	75	9	1053	74	9
69	9	782	70	9	64	9	1090	65	9
66	9	789	66	9	64	5	1091	64	5
64	8	791	65	8	61	5	1109	64	5
66	9	792	67	9	62	9	1111	62	9
72	9	794	68	9	64	9	1118	63	9
65	9	810	66	9	64	9	1199	65	9
65	5	814	65	5	60	9	23	60	9
65	9	815	65	9	61	9	33	63	9
64	8	899	65	8	62	9	36	63	9
66	9	901	67	9	66	9	38	66	9
65	9	916	69	9	65	9	39	67	9
69	6	923	70	6	62	9	41	61	9

Sheet 1 - 0 to 50   Start: 12:31:00   Stop: ____________

Recorded By: ar   Verified By: dw

Validation Test Truck Run Set - Pre

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 51 SPS WIM ID: 510100 DATE (mm/dd/yyyy) 3/1/2011

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
65	**9**	**42**	**65**	**5**	62	9	279	62	9
67	9	48	67	9	63	9	284	63	9
64	**4**	**98**	**64**	**6**	60	9	285	61	9
60	5	100	61	5	65	5	302	66	5
71	9	103	72	9	64	8	307	64	8
68	9	105	68	9	67	5	309	67	5
65	9	142	64	9	63	9	315	63	9
64	5	145	64	5	67	5	317	66	5
62	11	147	62	11	64	8	321	63	8
67	9	166	67	9	65	11	323	65	11
60	9	201	60	9	65	9	331	65	9
64	9	206	64	9	67	6	336	68	6
63	5	209	64	5	**52**	**15**	**349**	**53**	**10**
63	5	210	65	5	64	9	359	65	9
68	6	218	69	6	65	9	369	65	9
60	9	223	62	9	61	8	373	61	8
68	9	226	69	9	62	5	374	62	5
68	8	227	70	8	62	9	377	63	9
57	5	264	57	5	65	9	385	65	9
59	10	265	59	10	64	8	386	64	8
61	5	267	62	5	64	9	396	64	9
63	9	268	64	9	62	9	415	65	9
70	5	262	71	5	63	9	469	65	9
65	9	274	65	9	61	9	472	62	9
65	5	275	66	5	63	8	479	64	8

Sheet 2 - 51 to 100 Start: ____________ Stop: 14:03:25

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Pre

Traffic Sheet 20	STATE CODE:	51
LTPP MONITORED TRAFFIC DATA	SPS WIM ID:	510100
SPEED AND CLASSIFICATION STUDIES	DATE (mm/dd/yyyy)	3/2/2011

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
64	9	3453	64	9	63	6	3940	64	6
65	5	3478	65	5	61	5	3945	63	5
64	9	3599	65	9	66	9	3949	66	9
67	9	3600	67	9	66	9	4428	68	9
73	5	3647	72	5	64	9	4443	64	9
68	9	3737	68	9	55	11	4447	55	11
67	5	3751	68	5	75	9	4448	75	9
69	6	3767	70	6	63	6	4451	61	6
66	6	3797	67	6	69	9	4453	69	9
60	6	3802	62	6	68	9	4456	69	9
62	9	3806	63	9	65	5	4461	64	5
65	6	3810	66	6	57	9	4466	59	9
67	9	3813	68	9	62	9	4468	62	9
65	6	3823	66	6	65	9	4499	66	9
55	9	3824	55	9	63	9	4502	62	9
65	9	3830	64	9	67	9	4506	67	9
63	9	3832	64	9	**71**	**8**	**4511**	**71**	**5**
61	5	3835	63	5	67	5	4521	69	5
59	11	3901	59	11	59	9	4525	59	9
61	9	3915	61	9	74	5	4526	75	5
70	9	3918	70	9	65	9	4527	65	9
69	6	3919	70	6	70	6	4528	72	6
70	6	3920	70	6	62	9	4530	63	9
51	9	3931	52	9	62	7	4555	63	7
52	9	3933	52	9	59	9	4557	59	9

Sheet 1 - 0 to 50 Start: 7:51:01 Stop: 11:05:31

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Post

Traffic Sheet 20 LTPP MONITORED TRAFFIC DATA SPEED AND CLASSIFICATION STUDIES	STATE CODE: 51 SPS WIM ID: 510100 DATE (mm/dd/yyyy) 3/2/2011

WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class	WIM speed	WIM class	WIM Record	Obs. Speed	Obs. Class
71	**8**	**4563**	**71**	**5**	59	6	4709	59	6
64	**5**	**4570**	**65**	**4**	62	9	4719	63	9
60	9	4579	59	9	62	8	4727	61	8
62	9	4616	64	9	61	9	4728	62	9
67	9	4623	68	9	70	9	4731	69	9
65	5	4625	63	5	54	9	4740	55	9
65	9	4626	65	9	**65**	**9**	**4747**	**65**	**5**
61	9	4627	61	9	66	9	4753	67	9
67	5	4632	66	5	62	11	4756	62	11
59	9	4633	60	9	68	9	4761	69	9
62	11	4636	63	11	59	9	4763	59	9
68	9	4666	68	9	59	6	4764	59	6
66	9	4669	66	9	59	9	4771	60	9
60	9	4671	61	9	60	9	4774	61	9
56	9	4674	56	9	68	5	4779	68	5
57	9	4675	56	9	70	6	4810	72	6
65	9	4684	66	9	66	6	4816	67	6
59	6	4687	58	6	65	5	4822	66	5
60	9	4688	61	9	64	9	4826	64	9
47	5	4691	47	5	68	6	4834	68	6
61	5	4693	61	5	65	8	4838	67	8
65	9	4694	64	9	62	11	4841	63	11
60	9	4695	60	9	68	9	4893	68	9
65	9	4703	65	9	**67**	**15**	**4899**	**68**	**7**
67	9	4705	68	9	63	7	4900	64	7

Sheet 2 - 51 to 100 Start: 11:05:32 Stop: 12:20:11

Recorded By: ar Verified By: dw

Validation Test Truck Run Set - Post